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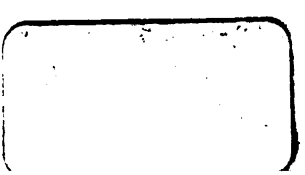

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STEVENS INDICATOR.

VOL. XIII. JANUARY, 1896. NO. 1.

THE TURBINE OF THE NIAGARA POWER CO.

BY PROF. DE VOLSON WOOD, C. E.

It has been proposed to utilize some 100,000 horse-power of the falls of Niagara.

For this purpose a bayou 250 feet wide and 12 feet deep, excavated for the purpose, more than a mile beyond the crest of the falls, conducts the water from the river to vertical shafts, in the lower ends of which are placed, or are to be placed, turbines which will have a head of about 136 feet; the tail races leading to a tunnel, which is about 21 feet high, about 18 feet wide, and 7,000 feet long, discharging into the river a short distance below the falls.

Already some parallel flow turbines furnish the power for an immense paper-mill, and two other turbines have been put in place and are furnishing power for a company manufacturing aluminum.

In the pit or excavation, where the latter are placed, it is proposed to place eight more such wheels, making ten wheels, each of which is to furnish about 5,000 horse-power.

We propose to speak of these two wheels.

They possess an unusual interest because of their great capacity, the great head of water, unusual in this country, and the distance from the wheel to the point where they deliver their power—being through a vertical shaft of about 140 feet.

Greater heads have been employed in Europe.

At St. Blaise a Fourneyron turbine was run with 354 feet head, but it was only 13 inches outside diameter and developed about 30

horse-power. Its speed was remarkable, making 2,300 revolutions per minute.

At Immerstadt a turbine was run under a head of 570 feet and developing 400 horse-power.

Industries gives an account of the mills at Terni, Italy, which were driven by several turbines of different sizes under a head of 595 feet, the largest of which developed 1,000 horse-power. These were symmetrical wheels as shown in Fig. 1.

FIG. 1.

Neither is the diameter of the Niagara wheel the largest. The outside diameter is 6¼ feet. The external diameter of the celebrated Tremont wheel at Lowell, Mass., was 6.756 feet.

This wheel, which was a Boyden wheel of the Fourneyron type, under a head of 13 feet, developed about 161 horse power. It ran continuously for 43 years, when it was removed to give place for one of more power.

The Boott center vent was 9.338 feet diameter, and under a head of 13½ feet developed 138 horse-power. The Humphrey, also

center vent, was 8.1 feet diameter, and under a head of 14 feet developed 270 horse-power.

The largest of the segmental wheels at Terni was 7 feet 9½ inches, inside diameter; and the one at Immerstadt was 8 feet 11 inches.

The capacity of the Niagara wheel is many times that of any here mentioned.

In this country turbines are usually made from fixed patterns of definite sizes to suit average conditions, are turned out in quantities, and kept in stock, to be purchased when wanted; but in Europe they are more generally made to order, designed for the particular place and conditions. So when the Niagara commission called for plans of wheels, the American manufacturers submitted their trade catalogues, and the European manufacturers submitted special designs. Among the designs considered was the American twin turbine on a horizontal shaft, with belt or rope transmission, but the difficulties encountered were so great that such plans were finally abandoned, and the design of Messrs. Faesch & Piccard, of Geneva, Switzerland, was accepted, the plan of which is shown in Fig. 2, for which the writer is indebted to the courtesy of Coleman Sellers, E. D., Professor of Engineering Practice, Stevens Institute, and President and Chief Engineer of The Niagara Falls Power Co.

The water passes from the lower end of the penstock *A*, Fig. 3, into the casing *B B*, thence through the distributers *b b b*, three of which are at the upper end of the case and three below; thence through the buckets *a a a*. The wheel is divided into six elementary wheels by transverse discs, three of which are above, where the water enters, and three below. The gate *c c* is a cylinder exterior to the wheel, and opens the wheel passages by being moved downward. The shaft *C* passes through the central part of the case, to the former of which the crowns of the wheel are firmly secured. The upper crown is solid, but through the upper end of the case are openings *d d*, through which water may pass into the space be-

Turbine of the Niagara Power Co.

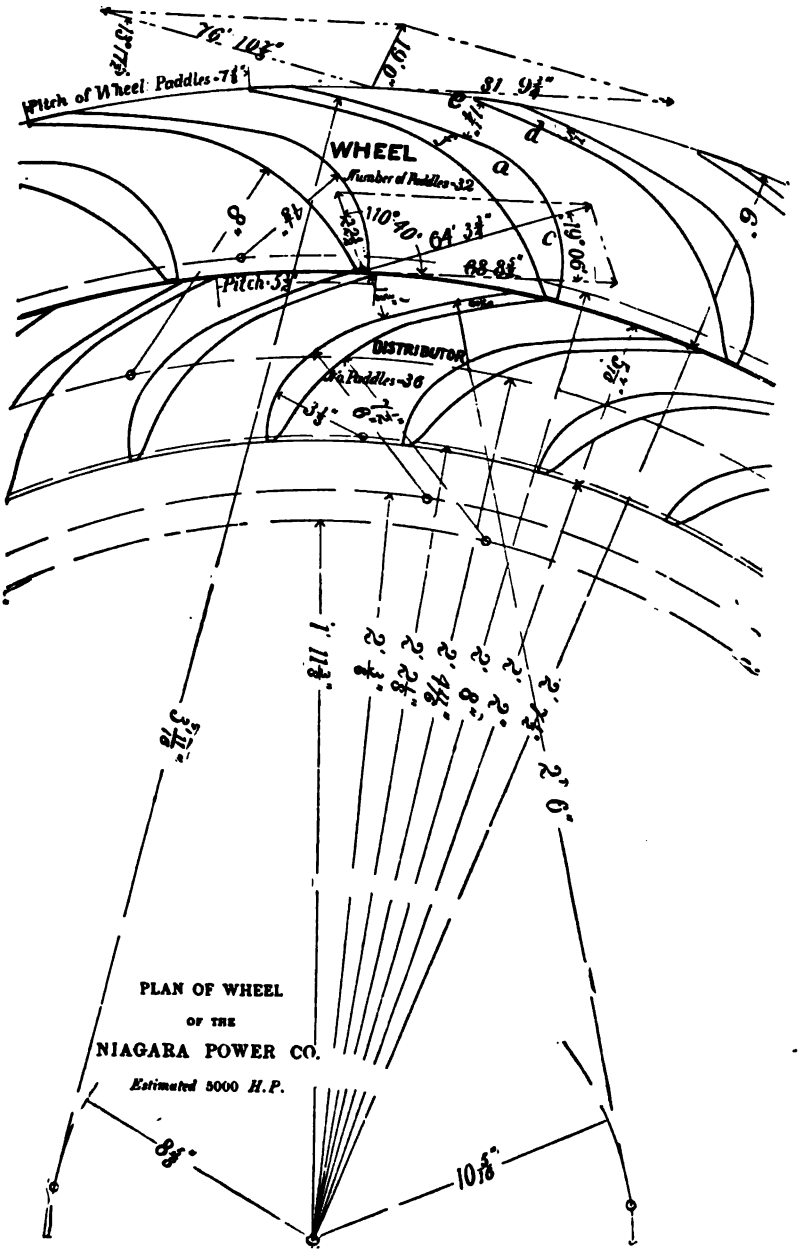

FIG. 2.

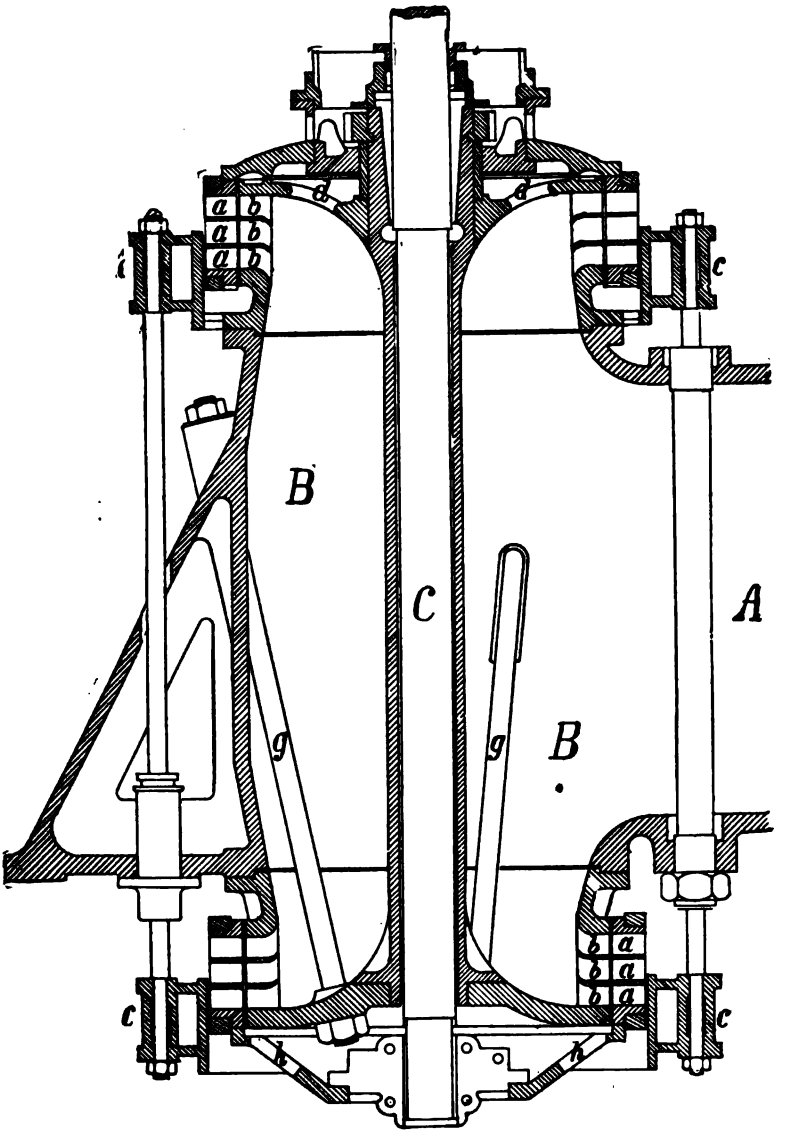

FIG. 3.

tween the upper end of the case and the upper crown of the wheel, which, acting by upward pressure, supports a part, or all, of the weight of the wheel, shaft, and attachments. The lower end of the case is solid, but the lower crown has openings *h h*, so that any water entering the space above it may readily escape and not produce a downward pressure upon the wheel. The lower end of the case is supported by three rods *g g* extending through the case, two of which are shown in the figure. The gate is regulated by a delicate and efficient regulator, so that the deviation from the velocity desired is less than 4 per cent. when the load is increased or decreased by 25 per cent.

The figures on Fig. 2 were used in the construction of the wheel. The wheel was made of bronze, and the buckets, partitions, and crowns immediately above and below the buckets are solid in one casting.

The principal data are:

External diameter	$2r_2$ = 6 ft. 3 in.
Internal diameter	$2r_1$ = 5 ft. 3 "
Width of crown	6 "
External diameter of distributing chamber	5 ft. $2\frac{7}{8}$ "
Internal " " "	4 ft. 4 "
Clearance of wheel	$\frac{1}{16}$ "
Width of distributing chamber	$5\frac{7}{16}$ "
Diameter of penstock	7 ft. 6 "
Number of buckets	N = 32. "
Number of guides	N' = 36. "
Depth of each chamber *a*	$3\frac{5}{8}$ "
Clear depth of six chambers *a a a*	1.81 ft.
Thickness of the horizontal partitions, each	1 in.
Terminal angle of guides	α = 19° 6′
Initial angle of buckets, about	γ_1 = 69° 20′
Terminal angle of buckets	γ_2 = 13° $17\frac{1}{2}$′
Total head, about	H = 136 ft.

The head will vary with the height in the river and the effective head will exceed the static head by more than 1 foot on account of the velocity in the penstock, so I will use for a comparison

$$H = 138 \text{ feet.}$$

The head will be about 5 feet less than this at the upper end of the wheel, and as much greater at the lower end, so that the lower end should run faster than the middle, and the upper end slower, for best effect, but we make a computation for the mean head only.

The initial angle of the buckets is marked as 110° 40′, the supplement of which in our notation is $\gamma_1 = 69° 20'$. But this is the mean angle between the face and back of the vane. We made a computation for the efficiency and speed using this angle; but it made the efficiency very high, 85 per cent., and the speed too low, 232 revolutions per minute. With another computation with large assumed friction of the water, we found

$$E = 79 \text{ per cent. hydraulic efficiency,}$$

and

$$n = 228 \text{ revolutions per minute.}$$

These revolutions are much less than those given in Fig. 2, or than has been found in practice. The face angle of the bucket, measured on a drawing of the wheel, is

$$\gamma_1 = 51°,$$

and with this angle we found results agreeing fairly with those found by Dr. Sellers, as communicated to the author, so we have used this value. This is our first opportunity of determining from actual trials whether γ_1 for a finite stream should be the angle made by the face of the bucket with a tangent to the wheel, or the mean angle, and the indication is quite clear that it should be the angle of the face.

We first inspect the figures that are on the design. The wheel was to make about 250 revolutions per minute and produce 5,000 horse-power.

The revolutions will depend upon the head and initial and terminal angles of the buckets, and the capacity upon the depths of the buckets.

As we are now reviewing the wheel, we take the plan as we find it, then assuming 250 revolutions per minute, we have:

$$\omega = \frac{250 \times 2\pi}{60} = 26.16 \text{ ft. per second for the angular velocity.}$$

$\omega r_1 = 68.30$ ft. velocity of initial rim.

$\omega r_2 = 81.8$ " " " terminal rim.

And if $\gamma_1 = 180° - 110° 40' = 69° 20'$ and $\alpha = 19° 00'$, the triangle of velocities gives

$V = 64.31$ ft., the velocity of quitting the guides.

$v_1 = 21.5$ ft. nearly, the initial velocity of the bucket.

Not knowing the head assumed in the computation, nor the pressure in the bucket, we could not compute directly the terminal velocity, but knowing that the velocities were inversely as the cross-sections, we found that if the ratio—whether measured or assumed—was 3.42, then

$v_2 = 3.42 \times 22\frac{1}{2} = 76.95$ ft. terminal velocity in the bucket,

$V_2 = 19$ ft. actual velocity of quitting,

and

$\theta = 113°$, direction of V_2, the quitting velocity.

These figures agree so nearly, almost exactly, with those given in Fig. 2, that we assume that they were obtained in this manner. If the wheel makes 250 revolutions per minute when producing its highest efficiency, under a head of 136 feet, and the other data be as given or assumed, the solution is correct; but otherwise, it is only an approximation, more or less rough.

If 430 cubic feet were discharged at a velocity of 76.95 feet, through 32 buckets, each 1¼ inches wide, the depth should be

$$y_2 = \frac{430}{\frac{1}{12} \text{ of } 1.25 \times 32 \times 76.95} = 1.68 \text{ feet.}$$

The actual depth of the six chambers is 1.81 feet; hence the capacity of the wheel should exceed 5,000 horse-power in the ratio 1.81/1.68, giving 5,300 horse-power.

This assumes that the buckets are properly made. It appears that the cross-section *a d*, Fig. 2, is slightly less than that at *f e*, whereas the former ought to be perceptibly larger, since the velocity of the water increases as it goes outward, so that if the section at *a d* is filled, that at *f e* will not be full, and the wheel will be a "pressure" wheel from the initial element to *a d*, and one of "free deviation" from *a d* to exit. This being the case, as determined from the plan of the wheel, the correct depth would be found by using the velocity at *a*, which will be somewhat less than at *e*, and also the width at *a*, which is also somewhat less than at *e*.

Hence the depth must exceed 1.68 for the required capacity. The wheel is not correctly designed for a pressure wheel. We would modify the design by using a shorter radius from *f* to *c*. This would increase the capacity of the wheel to about 5,900 horse-power, without reducing the efficiency. A thorough analysis would require a computation as a pressure wheel for the greater part and as one of deviation for the remaining part, but as this computation would be lengthy, we will now analyze it as if properly constructed as a pressure wheel of 5,500 horse-power. Then the volume of water flowing through the wheel per second will be:

$$Q = \frac{\overset{\text{H.P.}}{5{,}500} \times \overset{\substack{\text{ft. lb.}\\ \text{per sec.}\\ \text{I.H.P.}}}{550}}{\underset{\text{per cent.}}{81} \times \underset{\text{ft.}}{138} \times \underset{\substack{\text{wt.}\\ \text{cu. ft.}}}{62.4}} 100 = 433 \text{ cu. ft. per sec.}$$

By a computation not here given it was found that the width of the buckets would be about 1.08 inches instead of 1¼ inches; with this value the ratio of the initial to the terminal section would be about 4.25.

But for a finite stream these widths should be measured, especially the initial width, and this should be normal to an indefinite

number of the traces of buckets. This method gives about 4.00 or a little more. With the data :

$k_1/k_2 = 4.00$.
$r_1 = 2.675$ ft. internal radius.
$r_2 = 3.125$ ft external "
$H = 138.$ feet head.

$\mu_1 = 0.10 = \mu_2$, co-efficients of friction.
$\gamma_1 = 51°$ initial angle of buckets.
$\gamma_2 = 13° 17\frac{1}{2}'$ terminal angle of buckets.

I find* from equations established in my paper in Vol. XII., *Transactions of the American Society of Mechanical Engineers*, and also in my work on Turbines, soon to be issued, from equations (56), and following :

Speed when running at best effect....	252.5 rev. per min.
Maximum efficiency (hydraulic).....	83.4 per cent.
Velocity quitting the guides.....	54.5 feet per sec.
Velocity entering the bucket.....	21.3 " "
Terminal velocity in the bucket.. ...	85.3 " "
Velocity of quitting relative to the earth...	19.6 " "
Velocity initial rim.....	69.4 " "
Velocity outer rim....	82.6 " "
Terminal angle of guide.	14° 10′
Direction quitting.....	89° 53′
Volume of water	433 cu. ft. per sec.
Corresponding width of bucket.....	1.04 inches.

No allowance has been made for leakage through the $\frac{1}{16}$-inch clearance of the wheel. There are three such clearances, two at the lower part and one at the upper.

I find by computation that the inside pressure is 7,470 pounds per square foot, from which I find that the leakage will be about 15 cubic feet per second; hence the quantity flowing into the penstock should be

$$433 + 15 = 448 \text{ cubic feet,}$$

* The computations were made by Mr. F. D. Furman, M. E., Instructor in the Department of Mechanical Drawing, Stevens Institute.

according to which the leakage will be

$$\tfrac{15}{448} \times 100 = 3.35 \text{ per cent. of the whole;}$$

hence the efficiency referred to the water consumed will be 83.4 $\times 96.65 = 80.65$ per cent.

We may now recompute the volume of water, thus:

$$Q = \frac{5{,}500 \times 550}{62.4 \times 138 \times .8065} = 436 \text{ ft. per second, flowing through}$$

the wheel, or 451 flowing into the penstock.

The terminal angle of the guide, which is marked as 19° on the drawing, is larger than it should be for smooth working, our computation giving 14° 10′. Dr. Sellers has tested these wheels, and we are permitted to make the following extracts from his communication.

At the time of the test the total head from the surface of the water above the penstock to the centre of the wheel was $H = 135.113$ feet, and the water delivered to the penstock was

$$Q = 26{,}867 \text{ cu. ft. per min., } = 447.8 \text{ cu. ft. per sec.}$$

and the theoretical horse-power of the water,

$$H.P. = \frac{447.8 \times 135.113 \times 62.3}{550} = 6{,}864.$$

There was an electrical output of 5,335 horse-power, hence the actual efficiency of the wheel and dynamo combined was,

$$E^1 = \frac{5{,}335}{6{,}864} = 0.7785,$$

or 77.85 per cent., and if the dynamo yielded 97 per cent., as guaranteed by the makers, then the efficiency of the wheel system, including friction and leakage, would be,

$$E = \frac{77.85}{0.97} = 80.26 \text{ per cent.,}$$

and the power delivered at the upper end of the shaft would be,

$$H.P. = \frac{5{,}335}{0.97} = 5{,}500$$

Although the analytical solution and the test are both defective in regard to the exactness of the data and differ slightly in regard to the head, yet the general agreement is remarkably good. The actual static head was 135.1 feet, to which, if 1.4 feet be added for velocity in the penstock, we have an effective head of 136.5 feet, which is only 1.5 feet less than that assumed in the analysis. This difference should make no difference in the efficiency and about 1 per cent. in the delivery.

The efficiency of the dynamo was *assumed* to be 97 per cent., and if it were less, then the efficiency of the wheel exceeded 80.26; and if the leakage exceeded 15 cubic feet per second, then would the computed hydraulic efficiency be less than 80.65 per cent. The friction of the shaft should be relatively small. With such data as we could gather we made it between 15 and 20 horse-power, or about 0.3 of 1 per cent.; but we do not consider our data very reliable and hence the result should not be quoted in exact figures.

According to our computation, the velocity of the water in the penstock will be

$$v = \frac{433}{\frac{1}{4}\,\pi\,(7\frac{1}{2})^2} = 9.8 \text{ feet.}$$

The velocity as it enters the case will be.....		12.2	"
"	"	in the case just before entering the distributers will be.....	28.5	"
"	"	entering the distributers will be.....	30.4	"
"	"	quitting the distributers will be.....	55.3	"
"	"	entering the wheel relative to the bucket will be	21.3	"
"	"	quitting the bucket will be.....	85.3	"
"	"	" " wheel in reference to the earth will be	19.6	"

The main part of the vertical shaft, Fig. 4, is a tube of steel rolled and without longitudinal riveted seams; 38 inches outside diameter and ¾ inch thick.

There are two solid parts joining the tubes, as shown in Fig. 4, which form journals for the support of the shaft and wheel and are 11 inches in diameter, one of which is shown in Fig. 5.

The stress on the tubular part when running steadily at 252 revolutions per minute and delivering 5,500 horse-power, will be

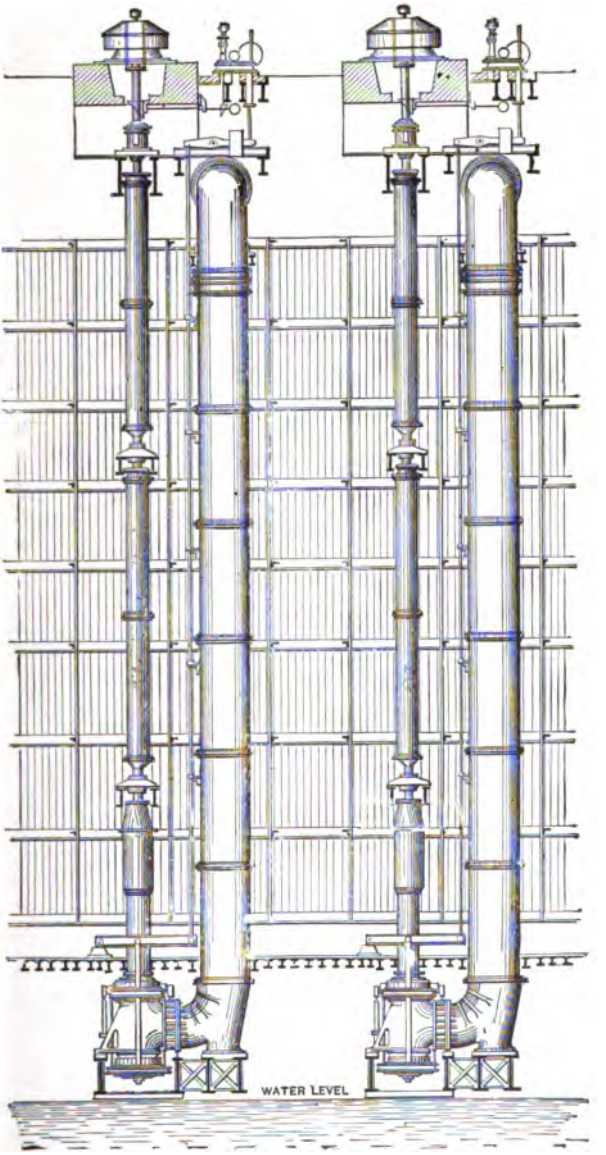

FIG. 4.

867 pounds per square inch, and the greatest stress on the solid part 5,260 pounds, or about $\frac{1}{10}$ of its ultimate strength.

We are not informed why the tubular part should be made six times as strong as the solid part. If the shaft were a tube of the

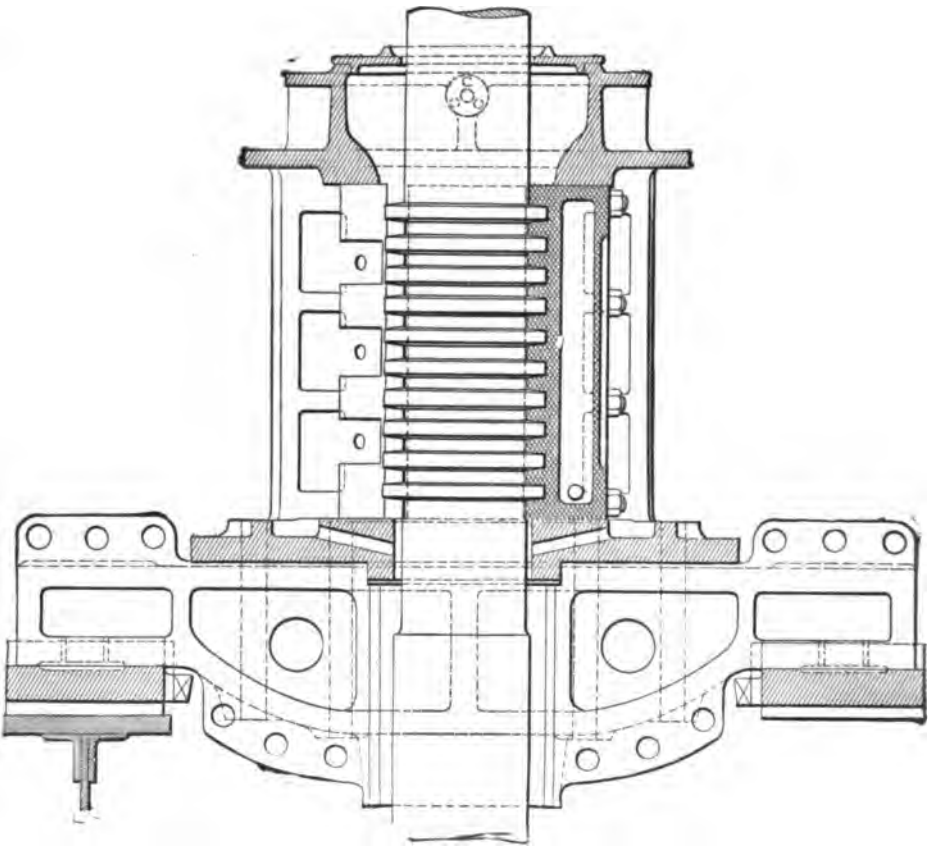

FIG. 5.

diameter given and 140 feet long, showing a modulus of elasticity to shear of 10,000,000 pounds, the shaft will be twisted about 4° 13′.

Such a shaft should be very strong and stiff to successfully resist sudden changes of load without endangering the strength or producing too much distortion.

A CURIOUS MECHANICAL MOVEMENT.

BY PROF. C. W. MacCORD, SC. D.

The mechanical combination illustrated by the accompanying figures possesses a certain interest as a solution of a problem involving conditions apparently contradictory, which may be stated as follows: A lever, normally held down by a spring or by gravity against a stop, can be raised at pleasure through a definite arc. It is required that the first upward movement shall raise a second lever, also against gravity or the pressure of another spring, to a certain position and leave it there; while the next upward movement shall release the second lever, allowing all parts to return to their original positions, and so on alternately; and it is also required that this shall be accomplished without the use of cams.

This does not sound like a difficult thing; but being thus substantially restricted to the use of levers and pawls, the task proved to be by no means as easy as it seemed. It is hardly necessary to say that the arrangement might be made much more compact; the figures show the construction of a merely illustrative model, purposely made in a rather sprawling manner for the sake of clearness; but it may be questioned whether the number of moving parts could be reduced, since, excluding the springs, the object is effected by means of five pieces—three levers, a pawl, and a detent.

In Fig. 1 these pieces are represented in the first position above mentioned, the lever A resting against the stop *a* fixed in the baseboard X X; it is furnished with a handle R, which is moved by hand to the position R′, and back again. This lever A is of one piece with the disk D, which turns upon the pin C, within a circular recess in X; in this recess is a coiled spring, the end of which, turning outward, fits at S into a hole in the second lever B, and keeps the latter in contact with A; three pins, K, L, and M, are fixed in B, and

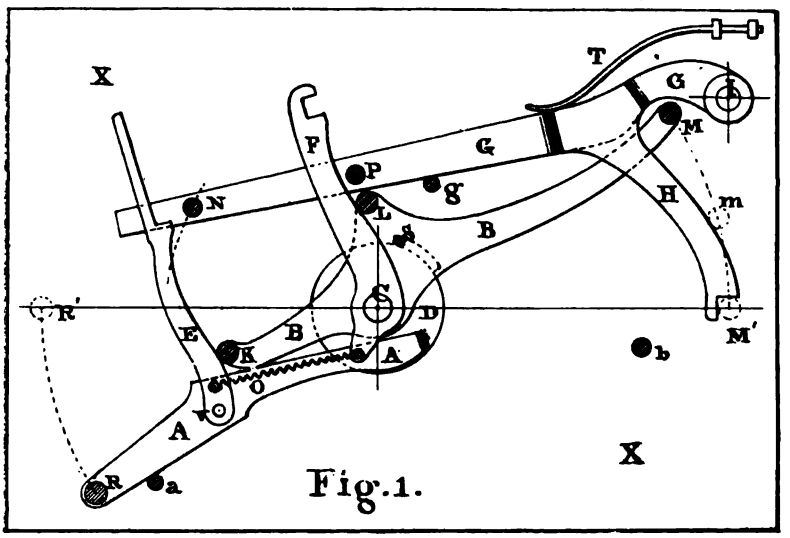

Fig. 1.

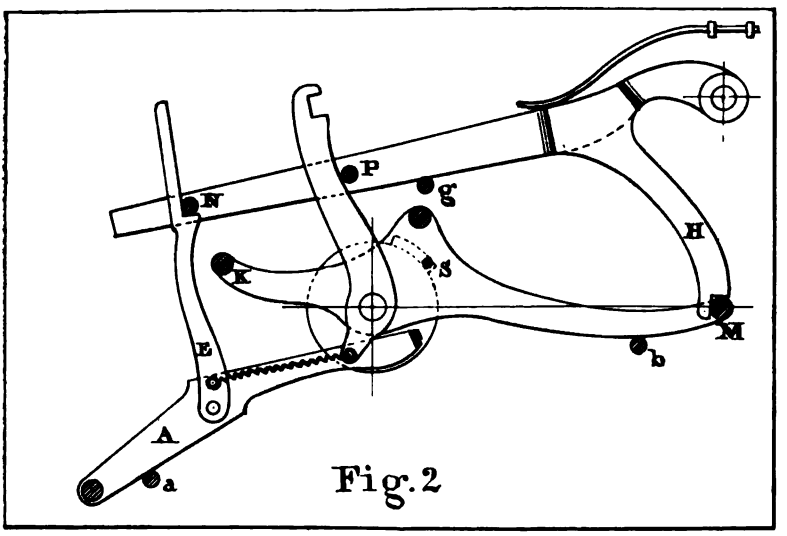

Fig. 2

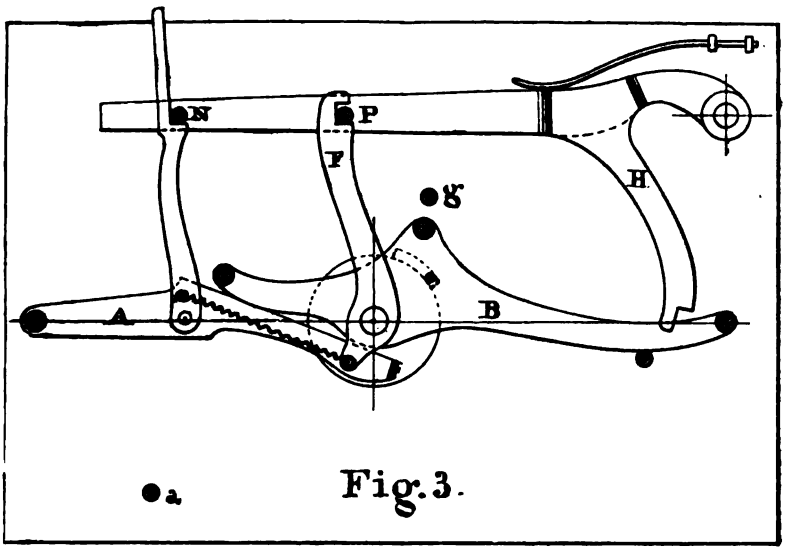

Fig. 3.

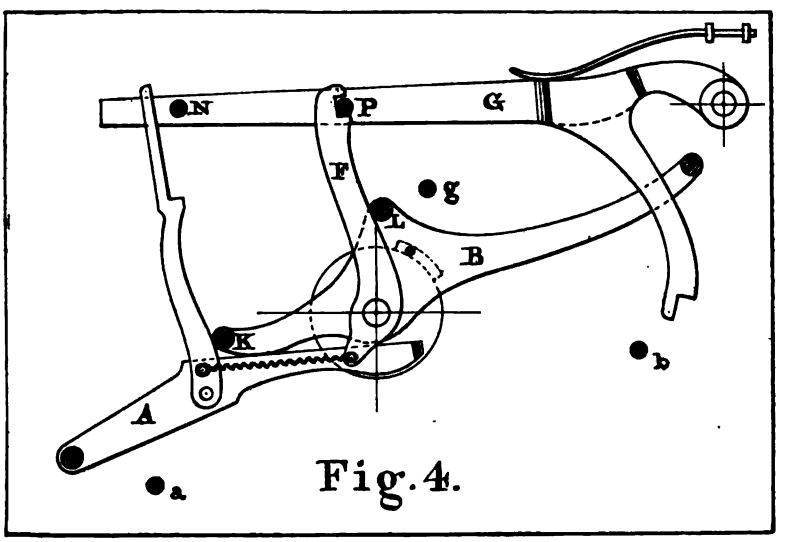

Fig. 4.

project outwardly from its front face. A pawl E is pivoted at *v* to the lever A, and a detent F turns upon the pin C; E and F are connected by a light helical spring O, and the points of attachment being above *v* and below C, this spring presses the pawl against the pin K and the detent against the pin L. The third lever G turns upon a pin I, and by a spring T is pressed down against a fixed stop *g*; this lever has a long projecting arm H, which also serves as a detent; and projecting from the face of G are two pins, N and P.

Upon raising the handle R, it is evident that at first A, B, E, and F will move as one piece; F will very soon be left behind, its motion being arrested by the pin P, and a little later E will be prevented from going further to the right by the pin N; not, however, until the shoulder of the pawl has passed above the pin without engaging with it. While R goes to R′, the pin M in the end of B will go to M′; but on reaching the position *m*, it comes in contact with H, which it pushes to the left until it can pass that arm; this raises the pin N, but not high enough to catch upon the shoulder of E, which by that time has passed far above it.

As soon as M reaches M′, the lever G falls, throwing the shoulder of H over the pin, which detains the lever B; on returning A to its first position, the pin K no longer obstructs the motion of E, which is now drawn to the right by the spring O, and the pawl engages with the pin N. A fixed stop *b* arrests the motion of both B and A when M reaches M′; and the result of this first movement of the handle from R to R′ and back again is to leave the parts in the positions shown in Fig. 2.

Now on the next upward movement of A, the lever G will be raised by the pawl E, thus releasing M; when R again reaches R′, the detent F will catch the pin P, and the various pieces will have the positions shown in Fig. 3. On the return of A, the lever G will be detained where it is for a time; the long finger of the pawl E sliding down over the pin N until, a little before reaching the posi-

tion shown in Fig. 4, the pin K, as the lever B is turned by the action of the spring S, will push the pawl to the left. In this last position, the pin L is just in contact with the detent F. As A continues to descend, F will be pushed to the left, releasing P and allowing G to fall against the stop *g*; but meanwhile E has gone so far that N will pass its shoulder, and when A reaches the stop *a* all parts will have resumed their normal positions, as shown in Fig. 1.

We have shown the lever B as actuated by a spring; and, supposing this to act promptly, it may be objected that the detent F is superfluous. But the conditions stated permit B to be actuated by gravity; in which case the action may be sluggish, as it surely would be in the application of the device to its original purpose, which may also be of interest to amateur mechanics, and we will therefore describe it briefly. In Figs. 5 and 6, D is a cylindrical chamber, to which gas enters by the pipe A; within this is a pipe E, which leads to a burner; C is a movable cell containing mercury; the lower end of D is filled by a perforated plug F, to increase the displacement. When the cell is lowered, as in Fig. 5, the gas flows to the burner, and the flow is stopped by raising the cell as in Fig. 6. In Fig. 7, C is the cell, hung on a lever turning on the fixed pin P, and *w* is a small weight on the arm of the lever. On the same pin P turns another lever B, on which is a weight W; and the proportions are such that C slightly overbalances *w* alone, but is slightly overbalanced by *w* and W together. In the position shown, then, the cell is raised and the gas shut off; if B be raised, no matter how quickly, *w* will follow slowly; and when B is released, no matter how suddenly, W will fall slowly,—the object is to prevent splashing in either movement of the cell.

In the ordinary forms of apparatus for turning on and lighting gas at a distance by electricity, a common gas-cock is used; which, if gas-tight, gives too much friction for the magnet to overcome, and if loose enough to turn with the requisite ease, leaks to a most objectionable extent. This mercury cell is perfectly tight, and free

from friction; it is here shown without regard to practical proportions, but in fact it can be shown that a half-ounce of mercury, with a vertical movement of three-eighths of an inch, will suffice to give an ample flow and secure a perfect seal, with no risk of "blowing through."

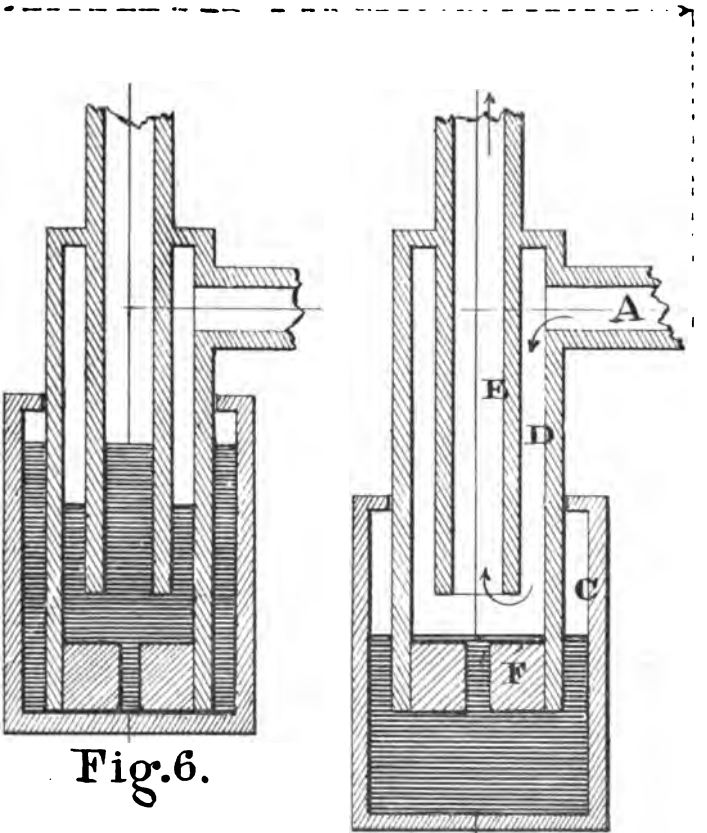

Fig.6.

Fig.5.

Again, two push-buttons are ordinarily used, one for lighting and the other for extinguishing; but the proposition here is, that but one button and one magnet shall be used; the first completion

of the circuit allowing the cell to fall, and the second permitting it to rise by the action of the overbalancing weights.

In order to effect this, it will be perceived that B in Fig. 7 corresponds to the lever B in the first four figures; the lever A is to be raised by the action of the magnet, and drawn down, in practice, by a spring. The upward motion of A, then, is in all cases sudden and rapid, but as B is not connected with the lever on which the cell is hung, this does not affect the motion of the cell in any way. Both A and G, however, are actuated by springs, and after touching the

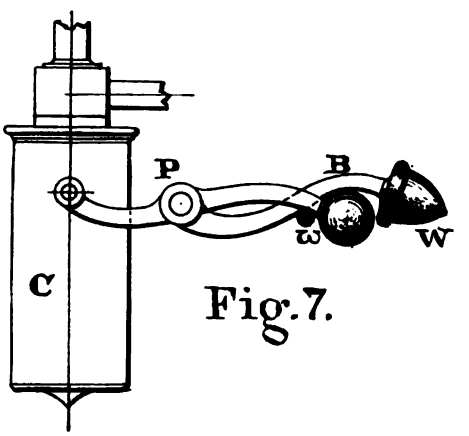

Fig. 7.

button the second time, it might happen that, the circuit being suddenly broken, H would fly back and catch the pin M before the slow action of the arm B had moved it far enough to escape this danger. An absolute safeguard against this contingency is provided by the detent F, which cannot be released until M has risen far above the shoulder of H.

In fact, since the motion of B, in the application of this device above described, is made sluggish with a definite purpose, the detent may not release the pin P until A has reached its lowest position. And this possibility, again, renders it necessary to make the

finger of the pawl E so long, that when the lever A is in the position shown in Fig. 1, and the lever G is in the position shown in Fig. 3, the finger would still rest against the pin N, even if B had not moved far enough to bring the pin K in contact with E. Then, no matter how slowly B may move, the pawl will be pushed out of the way of the pin N, before the latter is allowed to fall by the release of the pin P.

Thus it will be seen that the construction of this mechanical trifle requires, in order to secure absolute certainty in its action, quite careful consideration of a number of points, some of which are different from anything with which we have previously met. An examination of them may be of interest to those who find pleasure in the study of mechanical problems; besides, we have had frequent occasion to observe that a movement contrived by one person, with or even without a definite object in view, is subsequently found by others to be well adapted for use in designs of their own.

GASEOUS COMPOUNDS OF IRON AND NICKEL WITH CARBONIC OXIDE AND THEIR CURIOUS EFFECTS ON BURNER-TIPS, ETC.

BY PRESIDENT HENRY MORTON, PH. D.

Many years ago when what is known in popular nomenclature as "water-gas" came into large commercial use for general purposes of illumination as a substitute for "coal-gas," some of the companies manufacturing it met with a new and troublesome phenomenon consisting in the formation of mushroom-shaped deposits on burner-tips which deflected the flame and diminished its luminous intensity.

It was naturally supposed that these deposits consisted of some variety of coke or like carbon compound, but to make sure, some of them were sent to Dr. Durand Woodman, of New York, for analysis, and when his report came in that the material was oxide of iron, it was at first supposed that some mistake had been made, as it seemed incredible that iron in any way should have reached the burner-tips or entered into the formation ot these excrescences.

Investigation, however, showed that the deposits in question were certainly oxide of iron in substance, and the problem then presented was, where the iron came from and how it got to the burner-tips.

An extended comparison of experience among many companies, soon showed that the deposits on burner-tips were only formed where iron oxide was used in the process of gas purification.

Further observation also developed the fact that this formation of deposits at the burner-tips, was not uniform or constant, but varied with the condition of the iron oxide in the purifiers and was prevented when a thorough oxidation ot the iron had been secured,

but was notable whenever any reduced or metallic iron was present in the mixture.

To those not familiar with the details of the process, it may be desirable to explain that the oxide of iron used for gas purification, in this country, is usually prepared from metallic iron in the shape of "iron turnings" by exposing them, mixed with sawdust, to the air and sprinkling from time to time with "ammoniacal liquor," or treating with a solution of "copperas" or sulphate of iron.

In this treatment there was a risk that the iron would not be thoroughly oxidized, and that some metallic iron would be present when the so-called oxide was placed in the purifier.

As soon, however, as it was perceived that the troublesome deposit was connected with imperfect oxidation of the iron in the purifier, the remedy was easily applied by simply making sure that the oxidizing treatment was continued long enough to secure a thoroughly oxidized product.

Those having the matter in charge having reached this practical solution of the problem, were, as I believe, contented to leave it there, without pushing it to its scientific conclusion and proving exactly what was the way in which "water-gas" took up iron in the purifiers and carried it to the burners.

This phase of the subject was, I believe, independently investigated along another line.

In the *Journal of the Chemical Society*, London, 1890, Vol. 57, p. 749, Mond, Langer, and Quincke published a paper on "Action of Carbon Monoxide on Nickel," in which they showed that if this gas was passed over finely divided nickel at a temperature of 100° C. or lower (30° C. is recommended) the gas rapidly takes up the nickel, forming the compound indicated by the formula $Ni(CO)_4$, which is a gas, condensing readily in a freezing mixture of ice and salt into a clear colorless liquid whose boiling point is 43° C. at 751 mm. pressure. Its specific gravity is 1.3185 at 17° C. and at —25° C. it solidifies in needle-shaped crystals.

Its vapor has the density of 6.01, and if raised to the temperature of 60° C. will explode with violence.

These investigators, in this paper, state that they had tried to form similar compounds with other metals such as cobalt, iron, copper and platinum, but without success.

In 1891, however, in the same journal, Vol. 59, p. 604, Mond and Quincke publish a paper entitled "Note on a Volatile Compound of Iron and Carbonic Oxide," in which they relate how, by further investigation, they have succeeded in forming a compound indicated by the formula $Fe(CO)_5$ and which is produced by admitting carbonic oxide to carefully prepared finely divided metallic iron at the ordinary temperature of the laboratory, when the gas is absorbed by the metal. When this action has continued for 24 hours the vessel containing the iron is heated to about 120° C., when the compound $Fe(CO)_5$ or iron carbonyl distills off and is condensed in a freezing mixture at —20° C. as a somewhat viscous liquid of a pale yellow color. Its specific gravity at 18° C. is 1.4664. It distills without decomposition at 102.8° C. at 749 mm. pressure and solidifies below —21° C. into a mass of yellowish needle-shaped crystals. It is soluble in alcohol, benzine and like solvents, and at 180° C. is entirely decomposed into iron and carbonic oxide. Its vapor density is 6.4.

Returning to the nickel compound or nickel carbonyl, there are some curious facts about its actions and possible applications.

Thus ores or "mattes" containing metallic nickel in a porous condition, may have a current of carbonic oxide (such as is made in admixture with hydrogen, etc., in the first step of the water-gas manufacture) passed over it at ordinary temperatures. If the mixed gas, containing as it will the nickel compound, is then passed through tubes heated to only 200° C., it will deposit metallic nickel and can then be cooled and made to pass again over the nickel "matte," from which it will take up a fresh quantity of the metal. As the gas will act on nickel only, provided no iron is present,

chemically pure nickel can in this way be secured from the crude "matte."

As the metallic nickel is deposited in coherent films on heated surfaces, it has been found in this way possible to obtain articles of solid nickel by passing the gas through heated moulds, or to plate articles with nickel by immersing them, hot, in a current of the gas.

The same result can be obtained by immersing heated articles in solutions of the nickel carbonyl in benzole, benzine, or the like, or by applying such solution to heated articles with a brush.

For a full account of these compounds the reader is referred to the *Transactions of the British Association for the Advancement of Science*, 1891, p. 602.

THE MAGNETIC PROPERTIES OF NICKEL-STEEL.*

BY EDWARD P. BUFFETT, JR., M. E., '94.

The fact has long been ascertained that steel which contains about 25 per cent. of nickel is practically incapable of becoming magnetized (*Philosophical Magazine*, Nov. 13, 1874). Consequently it has been inferred that a smaller percentage of nickel would, in an analogous manner, partly destroy its magnetic properties. During the manufacture of a gigantic ring of such an alloy, for the Niagara "Cataract Construction Company," at the Bethlehem Iron Works, it transpired that this inference was altogether erroneous, and that steel containing about 5 per cent. of nickel possesses a magnetic permeability exceeding, perhaps, even that of soft iron.

It may be remarked that the higher percentages of nickel do not enter entirely into chemical combination with the steel, while the lower percentages do.

This fact would easily account for a diversity in properties.

With the exception of some experiments made by the Westinghouse Electric Company upon two of the grades treated in the present investigation, this field appears to be yet untrodden. In hope of attaining a definite conclusion regarding the matter, the tests about to be described have been undertaken.

GENERAL THEORY INVOLVED.

The methods of determining the magnetic properties of a metal and their underlying theories are so well known, that but brief mention is here necessary. The following matter is founded upon a series of papers by Prof. J. A. Ewing in the London *Electrician*, 1889-92.

An electric current passing through a solenoid of wire induces within it and parallel to its axis, a definite strength of field, or

* Graduating Thesis.

according to convention, a certain number of lines of force. If there be wound about this solenoid another solenoid with circuit closed, it will, at the time the lines are started, appropriate more or less of these lines of force in the formation of a transient current, which may be measured by means of a ballistic galvanometer.

Let, however, a bar of magnetic material be inserted in the primary solenoid, the current induced in the secondary will be greatly increased, owing to the formation within the material of a new set of lines called "lines of magnetization." The entire number per square centimeter of lines now residing within the primary coil are called "lines of induction" and are denoted by the letter B, those constituting the field by H, and those of magnetization by $4\pi I$. Therefore

$$B = 4\pi I + H \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Now $H = 4\pi C n$, where C is the current in absolute units, and n the number of turns of the primary coil per centimeter.

Unless, however, the bar to be tested be infinitely long, or in the form of a ring, or inserted in a massive yoke of soft iron, its ends, when it becomes magnetized, will exercise upon the field an effect tending to diminish it.

For this reason it is expedient to employ bars whose lengths are several hundred times their diameter; and even then this effect is appreciable. A fairly good correction may be made for it, however, by assuming the bar to be an ellipsoid of revolution, and employing a formula dependent upon certain qualities of the ellipsoid. The true strength of the field H will be equal to

$$H = 4\pi C n - N I \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

in which N is found by the following approximate formula:*

$$N = 4\pi \frac{a^2}{c^2}\left(\log_e \frac{2c}{a} - 1\right)$$

a and c being respectively the shorter and longer axes of the ellipsoid.

* This approximation is given by Ewing as practically perfect for bars of the length employed.

If the total number of lines induced in the secondary coil and measured by the ballistic galvanometer be denoted by Q, and if the cross-section of the bar be considered equal in area to that of the mean section of the primary solenoid, and denoted by S,

$$B=\frac{Q}{S}$$

But if S^1 be the cross-section of the solenoid and S that of the bar,

$$B=\frac{Q-(S^1-S)H}{S} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The process of determining the magnetization of a bar which is followed in the present case is to increase or decrease the magnetizing current by successive steps and note the deflections of the ballistic galvanometer which are thus caused. These correspond to increments in the number of lines Q, and at any stage of the experiment $Q=\Sigma\ (\Delta\ Q)$.

If a primary and a secondary coil be wound upon a cylinder of some non-magnetic substance such as wood, and so arranged that the secondary may be thrown into the galvanometer circuit instead of the test piece secondary, we may calibrate the instrument thereby.

If R_2 be the resistance of secondary test piece, including galvanometer circuit; R_4 the resistance of calibrating coil; n_3 the number of turns per centimeter in calibrating primary; N_2 the number of turns in the entire secondary test piece; N_4 the number of turns of calibrating coil; A_3 the area in square centimeters of the calibrating primary; C any current that shall, when passed through the calibrating coil, cause a deflection of the galvanometer of d_2 (the deflections reduced to proportionality to the quantity of the transient currents); and d_4 the deflection caused by ΔQ when the test piece is in circuit, the following formula is true;

$$\Delta\ Q = \frac{4\ \pi\ C\ n_3\ A_3\ N_4\ R_2\ d_2}{N_2\ R_4\ d_4}$$

Having now borrowed the foregoing formulas from Ewing, we proceed to apply and combine to suit our present needs.

It being desirable to express by a curve the relation between B or I, and H through a cycle of magnetization, and the comparison of B and H being the most important from a practical standpoint, we will eliminate I and find H in terms of the other quantities :

$$H = \frac{Q}{S^1 - \frac{4\,S\,\pi}{N}} - \frac{16\,\pi^2\,2\,S\,C\,n}{N\,S^1 - 4\,S\,\pi}$$

DESCRIPTION OF APPARATUS.

Three bars, containing different percentages of nickel, were wound with a primary solenoid of No. 14 B. & S., double cotton insulated copper wire over nearly their entire length.* At the middle was wrapped a secondary coil of 100 turns of No. 16 B. & S. double insulated copper wire. A wooden cylinder about 100 centimeters in length was similarly prepared, the secondary forming in this case, however, two layers. The resistances of the secondary coils were measured by means of a Wheatstone's bridge in connection with a sensitive Thompson galvanometer, as was also the remainder of the secondary circuit including the ballistic galvanometer.

The current was supplied by sixteen storage batteries arranged by series connections in eight pairs, which were, in turn, connected in series. But seven of these pairs were used at the same time. The latter connection was made through cups of mercury in a switch-board.

The positive current was divided by a shunt of German silver wire so that one-half of it might be measured by an ammeter which was not graduated sufficiently high to measure the entire current.

After this the current was united and entering a reversing key by a binding post opposite to that with which the negative pole was connected. By means of this key the current could be sent through the remainder of the circuit in either direction. From it, one wire

* To within a few centimeters of the extreme ends, which were rather rough.

led directly to the primary switch, the other side of the circuit proceeding to the opposite corner of the room, where it passed through a variable resistance, used for suddenly varying the current.

The fact that the experiments were carried on single-handed rendered it necessary that this resistance be placed at a spot whence the galvanometer could be read. The resistances were thrown out and in by dipping, in a saucer of mercury, wire attached to such bars of the resistance box as were found to give reasonable deflections of the galvanometer and changes of current.

By means of the primary switch, the primary coil on either the bar or the calibrating cylinder could be thrown into the circuit, which was thus completed.

In a similar manner, either of the secondary solenoids could be thrown into circuit by the secondary switch. From this the current was conducted to the galvanometer, passing through a resistance box, by means of which the amplitude of the deflections could be varied at pleasure.

The ballistic galvanometer was made from a Hartmann-Wiedemann type with bell-shaped magnet, by weighting the magnet with a fusible metal and substituting for the copper block in which it hung a wooden one.

To save time by damping the oscillations after taking a reading, two coils were placed behind it, through either of which, by pressing a key, a battery current could be sent; one being adapted to coarse and the other to delicate adjustment. The scale on which the thread was reflected by the galvanometer mirror comprised 38 divisions on either side of the centre, these being divided into five smaller ones. The readings are entered in the tables as *divisions and tenths of divisions*. The distance from the centre of the scale to the mirror was equal to 65 of these units; consequently if x were the reading, θ the angle of swing, and therefore 2θ the angle made by the reflected ray with that of incidence, $\frac{x}{65} = \tan 2\theta$.

But it is well known that the quantity of electricity is proportional to sin ½ θ, denoted in the formula by *d*.

$$\text{Therefore } d = \sin \tfrac{1}{4} \tan^{-1} \frac{x}{65}$$

A curve was plotted to express this relation, and by means of it, the readings were severally transmuted from x to d.

Both the primary circuit and the ends of the magnet caused marked displacements of the thread from its central position upon the scale. They acted sometimes in conjunction and sometimes in opposition, changing with each increment of current. Their effect could not be completely overcome, although in the arrangement of the apparatus the bar and galvanometer were placed as far as possible apart, and in such a way that the ends of the latter should point about north and south and a line perpendicular to it at the centre should contain the galvanometer. Even if the galvanometer were so adjusted that the index thread should stand at o before each deflection, an error would be registered in the reading taken; besides, greater inaccuracies might result from the time lost in this manner. It was deemed best, therefore, to make no attempt at precise adjustment, but to take readings on both sides of the scale, which would eliminate the effect of small errors caused not only by the current and the magnet, but by lack of precision in the adjustment of scale, galvanometer, etc.

In practice, the first reading on one side, then upon the opposite side, and a second upon the first were taken. In averaging them, allowance was made for the diminution of amplitude, which was found by comparison of a number of readings to be about $\frac{x}{40}$ for each single oscillation.

If x_1, x_2, x_3 were the readings, the mean value of

$$x = \frac{1}{4}\left(x_1 + 2x_2 + x_3 + \frac{4x_1}{40}\right)$$

Thus if $x_1 = 10.9$, $x_2 = 11.0$, $x_3 = 10.8$, $x = 11.2$ approximately.

The bars were demagnetized after each experiment, by decreasing the current by short intervals and reversing at each step.

DATA AND CALCULATIONS.

CALIBRATING COIL.

Number of turns in secondary (N_4)	100.	
Resistance of secondary	.4867	ohm.
" galvanometer, etc	1.1095	"
" complete secondary circuit (R_4)	1.5962	"
Mean diameter of primary	9.85	cm.
Area of section of primary	76.2013	sq. cm.
Number of turns in primary	535.	
Number of turns to the centimeter in primary (n_2)	5.374	
Length of primary solenoid	99.55	cm.

FIRST BAR.

CHEMICAL COMPOSITION.

Percentages—

Carbon	0.290
Manganese	0.780
Silicon	0.137
Phosphorus	0.022
Sulphur	0.030
Copper	0.069
Nickel	5.661
Iron (by diff.)	93.011
Total	100.000

Number of turns in primary..... 1500.
Number of turns in secondary (N_2)..... 100.
Number of turns to the centimeter in primary (n) 5.40
Resistance of secondary coil..... .1265 ohm.
Resistance of complete secondary circuit (R_2).. 1.2360 "
Diameter of magnet (a)..... 1.62 cm.
Sectional area of magnet (S)..... 2.0612 sq. cm.
Mean area of primary coil (S^1)..... 2.50246 " "
(S^1—S)..... .44126 "
Length of magnet bar (c)..... 282. cm.

By formula $N = 4\pi\left(\frac{a^2}{c^2}\right)\left(\log_e \frac{2c}{a} - 1\right)$

$$= 4\pi \frac{(1.62)^2}{(282)^2} \log_e \frac{2 \times 282}{1.62} - 1 = 0.002014.$$

This constant is the same for all the bars tested.

$$H = Q \div \left(S^1 - \frac{4\pi S}{N}\right) - \frac{16\pi^2 S C n}{N S^1 - 4\pi S}$$

$$= Q \div \left(2.50246 - \frac{4\pi \times 2.0612}{.00.014}\right)$$

$$- \frac{16\pi^2 \times 2.0612\, n C}{.002014 \times 2.50246 - 4\pi \times 2.0612}$$

$$= (325.493\, n C) \div 25.897 - 0.0000777\, Q.$$

The formula thus far applies to all the bars.

$$H = 67.87\, C - 0.0000777\, Q$$

$$= 6.787 \times \text{current in ampères} - 0.0000777\, Q$$

$$B = \frac{Q}{S} \frac{(S^1 - S)\, H}{S} = \frac{Q}{2.0612} - \frac{0.44126 \times H}{2.0612}$$

$$= .485143\, Q - 0.21408\, H$$

$$= .4852\, Q - 14.53\, C$$

$$\Delta Q = \frac{4\pi C n_3 A_3 N_4 R_2 d_2}{N_3 R_4 d_4}$$

$$= \frac{4\pi C \times 5.374 \times 76.2 \times 100 \times R_2 d_2}{100 \times 1.5962 d_4}$$

$$= 3223.87 R_2 \left(\frac{C}{d_4}\right) d_2$$

This formula applies to all the bars.

Experiments with calibrating coil, entered in the tables, give $\frac{C}{d_4} = 0.06039$, for the galvanometer as adjusted during all tests on the first magnet. Substituting this value, R_2 being 1.236,

$$\Delta Q = 240.636\, d_2.$$

If 2 ohms extra be thrown in the secondary circuit, R_2 becomes 3.236 and

$$\Delta Q = 630.0152\, d_2.$$

In working out the first and second tests of the first magnet, there was a trifling difference in the values used for n_3 and $\frac{C}{d_4}$ from those given above, and also in the methods of averaging the readings.

SECOND BAR.

CHEMICAL COMPOSITION.

Carbon	0.250	per cent.
Manganese	0.660	" "
Silicon	0.079	" "
Phosphorus	0.025	" "
Sulphur	0.024	" "
Copper	0.056	" "
Nickel	4.514	" "
Iron (by diff.)	94.392	" "
Total	100.000	

Resistance of secondary..... 0.1463 ohm.
Number of turns to the centimeter of primary..... 5.4364

The formula

$$H = \frac{(325.493\, n\, C)}{25.897} - 0.0000777\, Q$$

gives, by substituting in it the value of $n = 5.4364$,

$$H = 68.3288\, C - 0.0000777\, Q.$$
$$B = 0.485143\, Q - 0.21408\, H.$$
$$= 0.4852\, Q - (14 +)\, C.$$

The magnetization rises to such a high point in the case of this magnet and the next, that the part of B which depends upon C is neglected in the calculation.

$$\Delta Q = 3223.87\, R_2 \left(\frac{C}{d_4}\right) d_2.$$

$\frac{C}{d_4}$ is found to average 0.09574.

Without extra resistance the secondary circuit offers 1.2558 ohms and $\Delta\ Q = 387.622\, d_2$.

With 2 ohms in, $\Delta\ Q = 1004.9287\, d_2$.

" 4 ohms in, $\Delta\ Q = 1622.235\, d_2$.

THIRD BAR.

CHEMICAL COMPOSITION.

Carbon	0.200	per cent.
Manganese	0.550	" "
Silicon	0.066	" "
Phosphorus	0.021	" "
Sulphur	0.018	" "
Copper	0.043	" "
Nickel	3.217	" "
Iron (by diff.)	95 885	" "
Total	100.000	

Number of turns of primary to the centimeter ... 5.39043

Resistance of secondary ... 0.1502 ohm.

$$H = \frac{325.493\ n\ C}{25.897} - 0.0000777\ Q.$$
$$= 67.7622\ C - 0.0000777\ Q.$$
$$B = 0.4851543\ Q - 0.21408\ H.$$
$$= 0.4852\ Q - 14.5065\ C.$$
$$\Delta\ Q = 3223.87\ R_2 \left(\frac{C}{d_4}\right) d_2$$

$\left(\frac{C}{d_4}\right)$ is found to average 0.09574.

With 0 ohm extra, resistance of secondary circuit = 1.26 ohms,

$$\Delta\ Q = 388.896\ d_2.$$

With 2 ohms, $\Delta\ Q = 1006.001\ d_2$.
" 4 ohms, $\Delta\ Q = 1623.559\ d_2$.
" 9 ohms, $\Delta\ Q = 3166.792\ d_2$.
" 10 ohms, $\Delta\ Q = 3475.400\ d_2$.

EXPERIMENTS WITH CALIBRATING COIL, ON GALVANOMETER AS ADJUSTED FOR TESTING FIRST BAR.

No extra resistance used in secondary circuit.

The column headed *Am.* contains the currents in ampères; that headed x, the readings; and that headed d_4, the corresponding numbers proportional to the quantity of electricity

Am.	x	d_4	$\frac{C}{d_4} = \frac{Am.}{10\ d_4}$
4.87	21.758	8.067	0.06037
4.83	21.758	8.067	0.05987
6.50	29.702	10.695	0.06078
5.21	14.170	5.363	0.05985
4.10	18.140	6.698	0.06121
4.98	22.140	8.195	0.06077
4.86	21.982	8.130	0.05978
2.18	9.260	3.530	0.06176
5.78	25.618	9.365	0.06172
5.58	25.478	9.323	0.05985
5.60	25.616	9.373	0.05973
3.95	17.462	6.543	0.06037
3.08	13.390	5.085	0.06057
3.08	13 406	5.080	0.06063
4.83	21.834	8.950	0.05967
4.785	21.722	8.049	0.05945
		Average.....	0.06039

In the experiments on the second and the third bar the galvanometer adjustments were changed.

Experiments with calibrating coil upon galvanometer as adjusted for second and third bars gave $\frac{C}{d_4} = 0.09574$.

THIRD TEST OF FIRST BAR.

The first column *O* applies to the extra resistance which is thrown into the secondary circuit, expressed in ohms.

O. *Am.*	*x*.	d_4.	ΔQ.	*Q*	*H*.	*B*.
0....1.13	11.206	4.27	1024.8	1024.8	7.58	516.
2 ...2.32	17.174	6.46	4069.8	5094.6	15.26	2465.
3.37	11.532	4.37	2753.1	7847.7	22.19	3805.
4.40	15.628	5.90	3717.0	11564.7	28.80	5597.
5.41	10.528	4.01	2526.3	14091.0	35.60	6825.
6.525	10.754	4.08	2570.4	16661.4	42.90	8071.
7.35	6.218	2.45	1543.5	18204.9	48.40	8816.
8.99	9.624	3.69	2324.7	20529.6	59.30	9948.
0....9.65	7.550	2.88	691.2	21220.8	63.05	10286.
7.23	93.96	3.59	— 861.6	20359.2	47.47	9860.
5.28	98.50	3.75	— 900.0	19459.2	34.20	9452.
3.29	12.802	4.87	—1168.8	18290.4	20.81	8878.
1.11	18.806	7.03	—1687.2	16603.2	6.24	8048.
0.	12.512	4.75	—1140.0	15463.2	— 1.20	7512.
2..—1.115	9.866	3.76	—2368.8	13094.4	— 8.58	6355.
—2.30	23.656	8.70	—5481.0	7613.4	—16.19	3698.
—3.31	30.151	10.84	—6829.2	784.2	—23.08	380.
—4.28	28.894	10.43	—6560.9	— 5776.7	—28.55	— 2779.
—5.33	26.332	9.60	—6048.0	—11824.7	—35.25	— 5717.
—6.48	16.332	6.15	—3874.5	—15699.2	—42.68	— 7514.
—7.25	7.800	2.99	—1783.7	—17482.9	—47.84	— 8477.
—8.86	10.716	4.07	—2564.1	—20047.0	—58.51	— 9687.
—9.50	3.416	1.37	— 863.1	—20910.1	—62.87	—10126.
0..—7.12	10.402	3.96	950.4	—19959.7	—46.87	— 9674.
—4.72	10.828	4.12	988.8	—18970.9	—30.55	— 9198.
—2.98	10.504	5.11	1226.4	—17653.6	—18.83	— 8561.
—1.02	20.100	7.50	1800.0	—15853.6	— 5.68	— 7689.
0.	14.718	5.56	1334.4	—14519.2	1.13	— 7040.
2... 1.035	9.166	3.50	2205.0	—12314.2	7.958	— 5972.
2.10	20.326	7.57	4769.1	— 7545.1	14.836	— 3664.
3.03	27.336	9.93	6255.9	— 1289.2	20.66	— 630.
3.97	28.568	10.32	6501.6	5212.4	26.545	2523.
4.92	27.360	9.83	6192.9	11405.3	32.467	5524.
5.92	17.914	6.71	4227.3	15632.6	39.098	7574.
6.68	8.970	3.42	2154.6	17787.2	43.84	8619.
8.11	11.180	4.26	2683.6	20470.8	53.48	9917.
8.70	3.720	1.42	894.6	21365.4	57.34	10350.

The column headed *Am.* gives the current in ampères. x is the reading of scale. d_2 is the reading when reduced to a number proportional to the quantity of electricity measured by galvanometer.

In computing numbers under headings H and B, from those under *Am.* and Q, a slide rule was employed; and consequently they must not be considered precisely accurate to as many places as they are really carried out, which would be, in fact, superfluously exact. The slide-rule was, however, used in no calculation which might affect the position of more than a single point of the magnetic curve

It is to be noted that the signs of the numbers under x and d_4, which signs are omitted from the tables, are the same as that of the corresponding ΔQ, which is supplied.

CONCLUSION.

Making a general average of the amounts of induction of the three bars, as determined for a field in the neighborhood of 65, we have as follows:

	Percentage of Nickel.	Induction.
I....	5.661	10 500
II.	4.514	16 200
III.	3.217	18 300

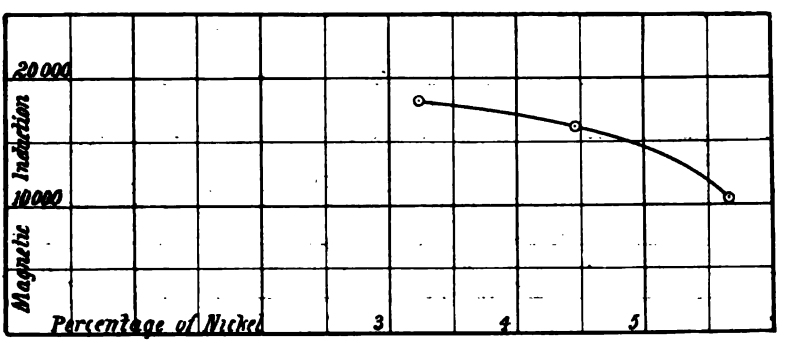

FIG. 1.

This relation is shown in the above curve. From it, we see that, within the limits of the investigation the induction increases with the diminution of the nickel alloy; but from the shape of the curve, we infer that a further decrease in the amount of nickel would add to the inductive power to a comparatively slight extent.

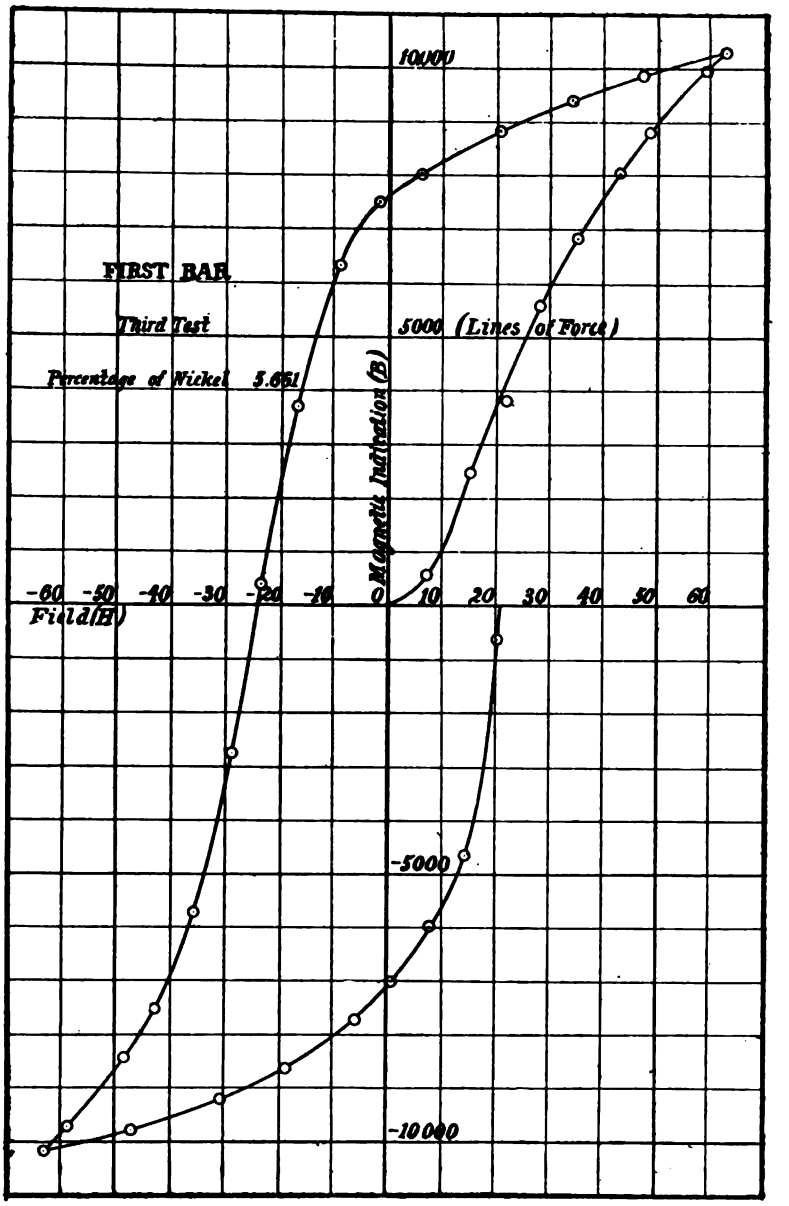
10000
FIRST BAR
Third Test
Percentage of Nickel 5.651
5000 (Lines of Force)
Magnetic Induction (B)
-60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60
Field(H)
-5000
-10000

FIG. 2.

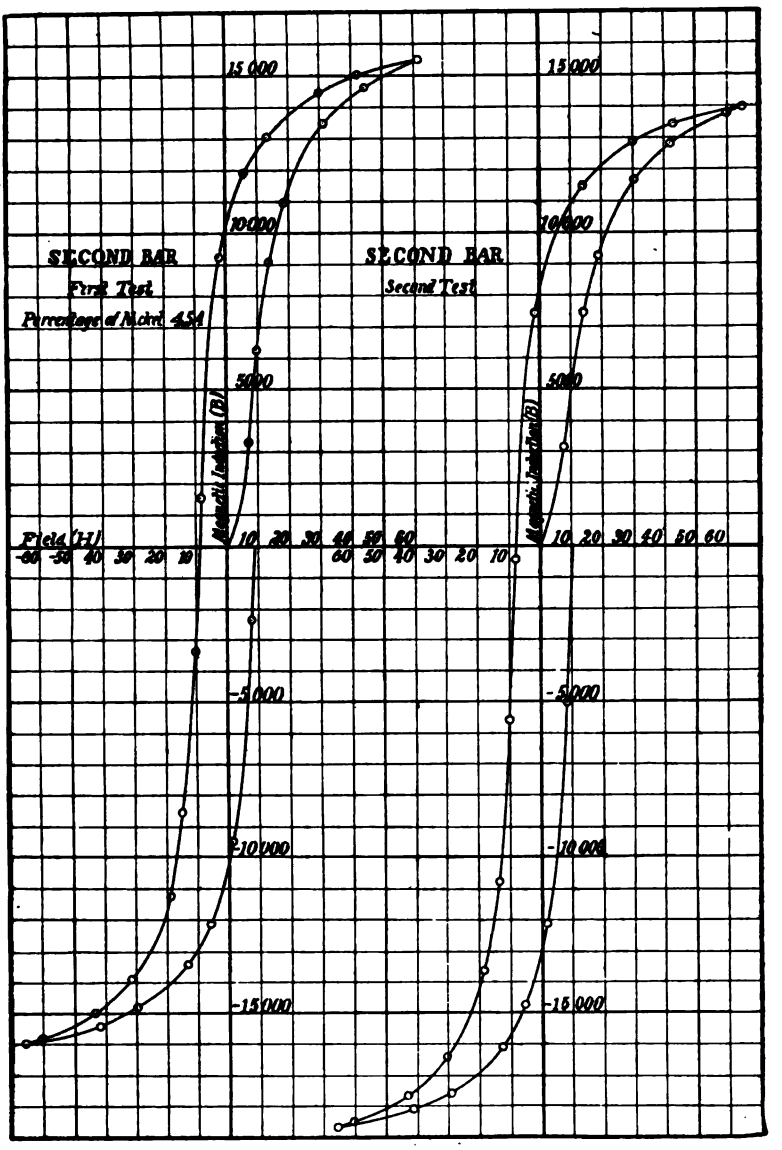
15000
10000
5000
-5000
-10000
-15000
SECOND BAR
First Test
Percentage of Nickel 4.54
Field (H)
-60 -50 -40 -30 -20 -10
10 20 30 40 50 60
SECOND BAR
Second Test
10 20 30 40 50 60

FIG. 3.

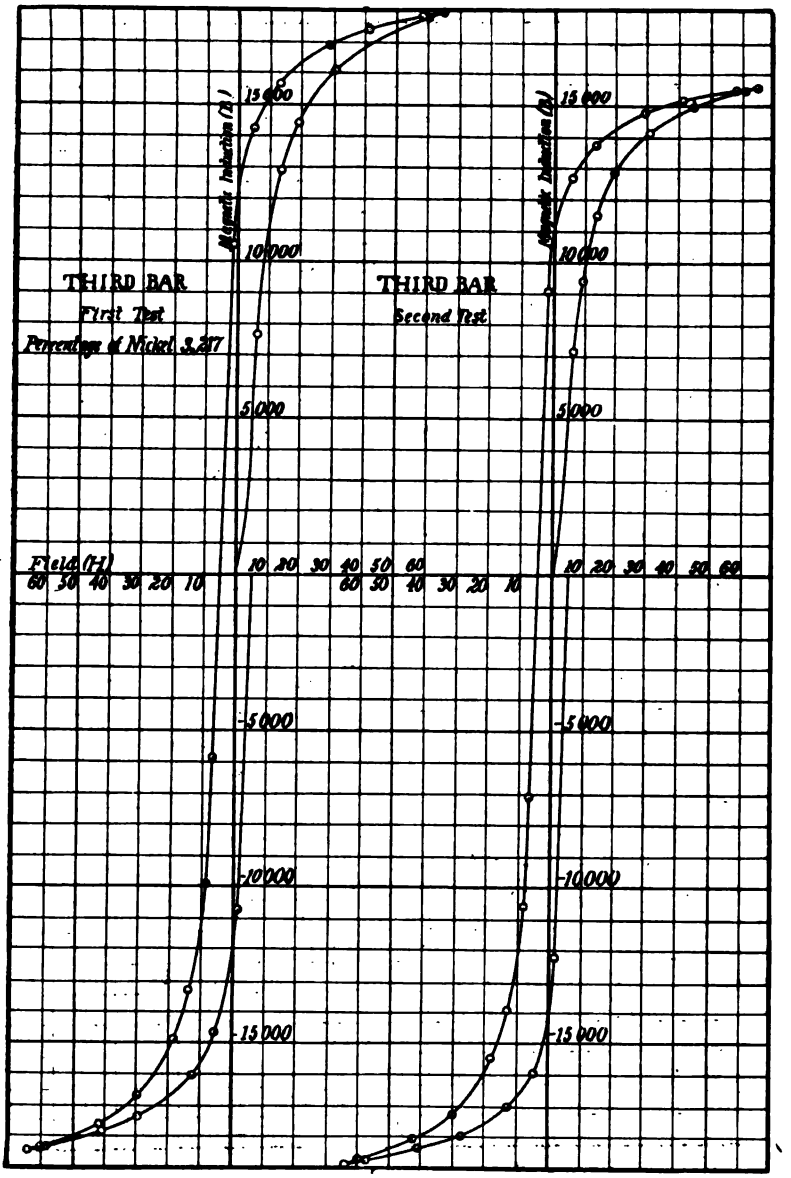
THIRD BAR
First Test
Percentage of Nickel 3.217
THIRD BAR
Second Test
Magnetic Induction (B)
15000
10000
5000
-5000
-10000
-15000
Field (H)
60 50 40 30 20 10
10 20 30 40 50 60

FIG. 4.

MEASUREMENT OF TEMPERATURES OF STEAM.

BY PROF. D. S. JACOBUS, M. E.

In boiler and in calorimeter tests it is often necessary to measure the temperature of steam. This is usually done by inserting a mercury thermometer in a well placed in the steam main, or pipe, through which the steam passes. Mercury or oil is used in the well to transmit the heat to the bulb of the thermometer

The object of this paper is to present experiments which were made to determine how nearly thermometers used in this way would register the correct temperature of the steam. The magnitude of the errors which may be involved by not heating the portions of the stems of the thermometers which project above the wells will also be discussed.

These experiments indicated that mercury wells of ordinary patterns will give the exact temperature of the saturated steam surrounding them, no matter what their thickness or form may be, provided they project into the steam space 1½ inches or more; whereas, with superheated steam, the temperature of the wells will be affected by their size and form.

It was also demonstrated that oil was much inferior to mercury for use in the wells, as a thermometer placed in a well containing oil responded more slowly to changes of temperature than if placed in a well containing mercury. In the case of a short well the use of oil would cause the thermometer to register too low, on account of the fact that the oil is such a poor conductor that the heat would not be imparted to the bulb rapidly enough to make up for the heat transmitted to, and radiated from, the portion of the stem of the thermometer which projected above the well.

In all cases a correction must be made if the mercury in the stem of the thermometer projects above the well. This correction is sometimes a large one. For example, in a thermometer used to measure the temperature of steam at the pressure of 60 pounds above the atmosphere, in which the column of mercury projecting above the well was about 9 inches long, and the reading to which the thermometer was immersed in the well was 40° Fahr., the correction amounted to 5° Fahr.

To eliminate the error due to not heating the stems of the thermometers, it has been our practice to calibrate the thermometers in the wells in which they are to be used, or in wells of the same depth, surrounded with saturated steam at a known pressure, and, therefore, at a known temperature. For example, if the number of degrees of superheating in the steam leaving a boiler is to be measured, the reading of the thermometer, with steam which is slowly condensing in the pipe, is determined, and the difference of the readings at a given pressure, for the steam which is slowly condensing and for the superheated steam, gives the number of degrees of superheating. To obtain the reading for steam which is slowly condensing, the main is allowed to remain open to the boiler, and is shut off at a point beyond the thermometer, so that the steam in the main is practically in a state of rest. If the steam is superheated at the time the main is closed at a point beyond the thermometer, the temperature registered by the thermometer for a given steam pressure will gradually fall until the reading of the thermometer is constant for a given steam pressure, and this constant reading for a given pressure is the reading for saturated steam.

This method was pursued in the test of the Pawtucket engine with saturated and superheated steam,* and since that time all thermometers we have used in steam pipes have been corrected in a similar way.

* *Transactions* A. S. M. E., Vol. XIII., p. 194.

The readings of the Bristol thermometer* are independent of the amount to which the capillary tube leading from the bulb to the pressure-recording device is heated; the Bristol thermometer, therefore, possesses an advantage over a mercury thermometer in this respect. If used to measure the temperature of steam, the bulb of the Bristol thermometer must be placed in direct contact with the steam, or it must be used in a well containing mercury. If used in a well containing oil, there may be a considerable error, which is not caused through any fault of the instrument, but from the fact that the oil is a poor conductor of heat.

In addition to determining the relative sensitiveness of thermometers placed in wells which contained oil and mercury, a comparison was made of thermometers placed in a current of superheated steam, which came in direct contact with their bulbs, and of thermometers used in wells. The sensitiveness of the Bristol Recording Thermometer was also compared with the sensitiveness of mercury thermometers used under the above conditions.

The bulb of the Bristol thermometer contained amylic alcohol. The bulb was three-eighths of an inch in diameter and five inches long.

The tests indicated that when the thermometers were placed directly in a current of superheated steam, and the amount of steam flowing by them was considerable, the Bristol thermometer was as sensitive as the mercury thermometer. The Bristol thermometer, with the bulb placed directly in the steam, was more sensitive than a mercury thermometer placed in a mercury well.

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* The Bristol thermometer consists of a bulb of considerable size containing a volatile fluid, which is partly evaporated on being heated to the temperature which is to be measured. The pressure of the vapor is communicated to a gauge by means of a tube of very fine bore. The quantity of liquid in the bulb is such that it is not wholly evaporated at the maximum temperature for which the instrument is designed, so that the pressures recorded by the gauge correspond to the temperatures of the saturated vapor in the bulb. The pressure gauge is graduated so that the readings represent temperatures instead of pressures.

If the flow of steam was a limited one, there were conditions under which a sudden change would not be recorded as rapidly by the Bristol thermometer as by a mercury thermometer placed in direct contact with the steam. The tardiness of the Bristol thermometer in the latter case was due to the heat required to evaporate the alcohol in the bulb. This effect will not be appreciable in ordinary use, and has but little influence for a rate of flow of one pound of superheated steam per minute, which is about the rate of flow in a Barrus calorimeter of the usual construction.

When used in a Barrus calorimeter the Bristol thermometer responds much more quickly to a change of conditions than a mercury thermometer placed in a well containing mercury; and a mercury thermometer in a well containing mercury responds more quickly than one placed in a well containing oil.

No tests were made to determine if the readings of the Bristol thermometer would be correct after a long period of use. All the results given in this paper are for a thermometer specially made for the purpose, the temperature scale of which was determined and graduated just before making the tests.

The temperatures given in the ordinary steam tables are those registered by an air thermometer; consequently, even if we had the correct readings with a mercury thermometer, they would have to be altered so as to correspond to the readings of an air thermometer, before the results could be used for interpolation in a steam table, or for obtaining the number of degrees of superheating. In calorimetric work the temperatures must also be those registered by an air thermometer. If, therefore, the readings of a mercury thermometer have been determined under known pressures of saturated steam, and consequently at known temperatures by an air thermometer, we can obtain the corrections which will reduce the readings of the mercury thermometer to equivalent ones for an air thermometer. These are the corrections that are required in ordinary work.

We will describe the apparatus now in use at the Stevens Institute for this purpose,* and afterward discuss the experiments in detail which lead up to the conclusion presented in the first part of this paper. The apparatus is shown in Fig. 1.

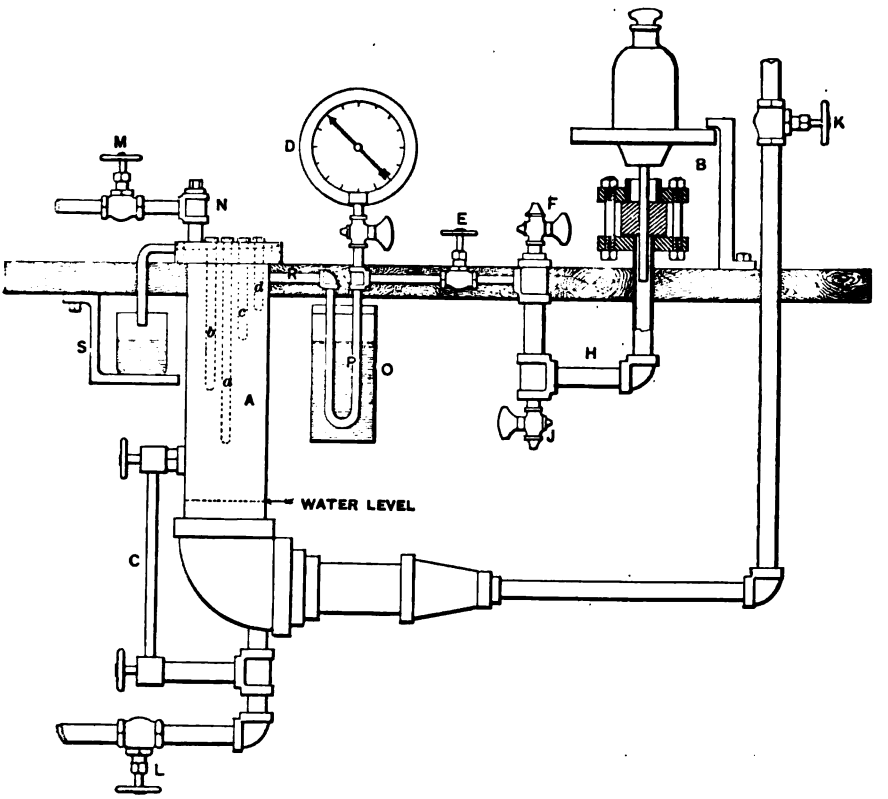

FIG. 1.

A is a reservoir formed of a length of 6-inch pipe, the top of which is closed with a cap. Seven mercury wells of various lengths, four of which are marked *a b c* and *d* in the sketch, are inserted in

*A description of this apparatus was presented at the New York meeting of the American Society of Mechanical Engineers, and will appear in Vol. XVII. of their *Transactions*.

the cap. Steam is brought to a known pressure in the reservoir A, and on entering, passes through water at the bottom of the reservoir. The water-glass C indicates the height of the water. The pressure is measured by means of the plug-and-weight device B. The bottom of the plug is on the same level as the pipe R. D is a gauge which is used to show the approximate pressure. The U-shaped pipe H is filled with oil. Before measuring the pressure the petcock F is opened slightly, in order to remove any air that may be lodged in the small pipe leading to the pipe H. The siphon P is cooled by water contained in the can O. The petcock J is used to remove any water that may collect at the lower part of the pipe H, after which the pipe is refilled with oil at F. The accumulation of water in H is caused by leakage of oil around the plug of the weight device, and as this is a small amount, there is but little water drawn from the petcock J.

The valve M is opened slightly throughout the tests, to permit steam to circulate continuously throughout the apparatus.

K is a throttle valve for the adjustment of the steam pressure in the reservoir A. The plug N is removed for calibrations at atmospheric pressure. The valve L is used to adjust the water level. S is a vessel to receive any mercury that may overflow from the wells.

In measuring the pressure by means of the weight device B the pan is spun around so as to eliminate the friction. The diameter of the plug is 0.5 of an inch, and of the hole 0.5005 of an inch, both being ground true. The average diameter of the hole and plug is used in calculating the pressure. The difference in the pressure, if the diameter of the plug, or the diameter of the hole, were employed instead of the average diameter, would amount to about one-tenth of a pound in one hundred, and the corresponding variation in temperature would be about one-sixteenth of a degree Fahr.

The weights, which are sealed bottles filled with shot, were adjusted to correspond with a standard set of kilogramme weights; which were, in turn, compared with weights made by the Fairbanks Co.

The errors due to not heating the portion of the stem of a thermometer which projects above a mercury well diminish if the thermometer is placed in a deeper well, and disappear when it is immersed so that all the mercury in the stem is heated to the maximum temperature. For example, with a thermometer in which there was an error of 7¼° Fahr., for steam at a pressure of 120 pounds per square inch above the atmosphere, when placed in a well 1¾ inches deep, the error was 6¾ degrees when immersed in a 2½-inch well; 5¾ degrees in a well 3¾ inches deep; 4¾ degrees in a well 5¾ inches deep; 2¼ degrees in a well 9¾ inches deep, and the thermometer read correctly when entirely immersed in the well.

It is interesting to note how nearly the mercury thermometers in use to-day agree with those employed by Regnault in measuring the temperatures of saturated steam.

The readings, for given steam pressures, of six thermometers made by Mr. H. J. Green, are given in Table I.* All the thermometers, with one exception, had been used in previous tests. The results in the table are corrected for the variations at 212° Fahr., due to continued use, and in each case the thermometers were submerged in the wells so as to heat the entire amount of mercury in the stems. The graduations were such that the temperatures could not be read closer than one-quarter of a degree Fahr., and, therefore, the maximum error, due to reading, was one-half of a degree Fahr. The average reading of Mr Green's thermometers at each pressure differed less than one-half of a degree Fahr. from the readings of Regnault's thermometers, which indicated that Mr. Green's thermometers agreed with those of Regnault to within the error of reading their scales.

The bulbs of the thermometers made by Mr. Green are all of the same kind of glass. After a long investigation of the matter, Mr. Green, in 1889, had made for him by Messrs. Schott & Gen, of

* This table was also presented at the meeting of the A. S. M. E., and will appear in Vol. XVII. of their *Transactions*.

TABLE I.

Readings of Mercury Thermometers in Degrees Fahrenheit Corresponding to Various Steam Pressures Comparison of Readings of Thermometers Made by H. J. Green, With Readings of Mercury Thermometers Used by Regnault in Measuring the Temperature of Saturated Steam.

Number of Thermometer.		Pressures at which Readings were taken in Pounds per Square Inch Above Atmosphere. Pressure of Atmosphere, 14.70 Pounds.				
		120	100	50	60	40
1		2	3	4	5	6
817		351¼	339¼	325¼	308½	287⅜
900		351¼	338¼	324¼	307¾	287¼
463		351¼	338¾	324¾	308	287¼
461		351¼	338½	324½	308	287¼
831		350½	338	324¼	308	287
* 821		351	338¼	324¾	308½	287½
Average of first four.....		351.5	338.7	324.7	308.1	287.4
Reading of Regnault's Thermometers.	Mercury	351.6	239.1	324.8	308.1	287.4
	Air †	349.8	337.6	323.7	307.1	286.5

Thermometers.									Degrees Fahrenheit.
No. 817 has a stem about 19 inches long graduated from									27 to 430
" 900	"	"	"	16	"	"	"	"	15 " 450
" 463	"	"	"	17½	"	"	"	"	94 " 406
" 461	"	"	"	11½	"	"	"	"	192 " 406
" 831	"	"	"	15½	"	"	"	"	90 " 610
" 821	"	"	"	16	"	"	"	"	80 " 620

* Not included in average, as the graduations were closer together than in the other thermometers, and the probable error of reading was therefore greater.

† The temperatures measured by the air thermometers are those given in the ordinary steam tables.

Jena, Germany, a pot of glass supposed to be of the same composition as that used by Crafts in his experiments on high-temperature thermometers,* Weidmann,† Pernet,‡ and others. The peculiarity of this glass is due to the fact that it contains about 7 per cent. of oxide of zinc, and no lead. This one pot of glass has been used to form the bulbs only of his thermometers, and he considers that he will have enough bulb-glass from this one pot to last a lifetime.

As the amount of mercury in the stem of a thermometer is a small fraction of that in the bulb, the expansion of the glass in the bulb practically governs the variations in the readings of the thermometers due to the expansion of the glass. By employing the same glass for all the bulbs, Mr. Green has, therefore, been able to produce thermometers which are exactly comparable with each other. That this is the fact is substantiated by the results of the tests given in Table I.

The greatest variation at 212 degrees found in any of the thermometers was three-quarters of a degree Fahr. Thermometers No. 461 and 463 had been used in a test which was made at intervals, one or two days apart, of about three hours each, and which extended over two months. In this test thermometer No. 461 was placed in direct contact with a current of superheated steam at atmospheric pressure. The temperature of the steam averaged about 270° Fahr., and was continually fluctuating between a range of about 250 and 290° Fahr. Thermometer No. 463 was used for a portion of the time under the same conditions as No. 461, and the remainder of the time it was placed in a mercury well for measuring a temperature of from 325° to 350° Fahr. No. 900 was used under the same conditions as No. 461, in a test which extended over

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* *Comptes Rendus*, Vol. XCV., 1882, page 836, and many other papers on the subject of thermometers.

† *Annalen der Physik und Chemie*, 1886, Vol. XXIX., page 214.

‡ *Comptes Rendus*, Vol. XCI., 1880, page 471. *Journal de Physique*, 1881, page 520, etc.

about one week, and was placed in a mercury well at about 325° Fahr. in another test of the same duration.

Thermometers No. 821 and 831 had been used for miscellaneous work, one having been employed to measure the flue temperature in a boiler test, where it was heated, a number of times, over 500° Fahr., and some times as high as 600° Fahr.

No. 817 had been in use but little before taking the readings given in Table I.

All thermometers were raised and lowered in temperature a number of times before taking the readings, so as to produce the corresponding amount of depression, and insure constant readings at given temperatures.

Three-quarters of a degree variation in the readings is a small change for thermometers used under the above conditions, and shows that the glass in the bulbs was thoroughly annealed.

Mr. Green's method of annealing high-temperature thermometers is to place them in lampblack, and subject them to the temperature of 450° Fahr., continuously, for 150 hours, cooling them very slowly at the end of this time. His thermometers are graduated by determining points at 32° Fahr. and 212° Fahr., and calibrating for all other temperatures, so that each degree represents an equal volume of mercury. The 32-degree point is obtained by allowing the thermometer to remain at least 30 hours in the ice, to destroy any depression due to ordinary temperature changes. The 212-degree point is obtained after the 32-degree point. In obtaining the 212-degree point the thermometer is placed in the steam, and removed a number of times until the corresponding depression is produced, and the reading is constant.

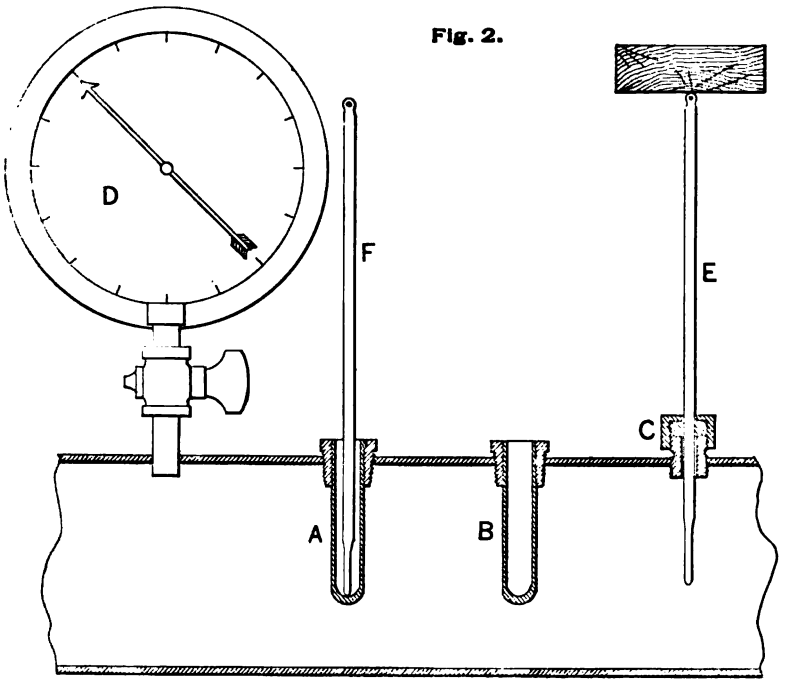
EXPERIMENTS IN DETAIL.

EXPERIMENTS MADE TO PROVE THAT MERCURY WELLS INDICATE THE EXACT TEMPERATURE OF SATURATED STEAM.

In the first experiment a thermometer E, Fig. 2, was inserted through a stuffing-box C so that the bulb came in direct contact with

steam at 80 pounds pressure per square inch above the atmosphere. The reading of this thermometer was determined at a given pressure, measured by the gauge D, together with the reading of another thermometer F placed in the mercury well A. After recording a number of readings the thermometer E was removed from the stuffing-box and placed in the mercury well B and a second set of readings was taken. After correcting for the variation in the read-

Fig. 2.



ing of E, due to the direct pressure of the steam on the bulb, the reading when used in the mercury well was found to be the same as when the bulb came in direct contact with the steam.

The thermometer E was heated to the same height on the stem when placed in the mercury well B, as when it passed through the stuffing-box C. The well B was 3 inches deep. The variation in the reading of the thermometer E, due to the steam pressure

acting directly on the bulb, was determined before and after the time it was used in the stuffing-box C, by placing it in a similar stuffing-box attached to a reservoir of oil. The oil in the reservoir was heated until the thermometer registered the same as when placed in the stuffing-box C. The pressure of the oil in the reservoir was then raised quickly to 80 pounds per square inch, and the variation in the reading of the thermometer was noted. The pressure was then lowered, and the variation in the reading again noted. This operation was repeated a number of times, and it was found that the error due to an increase of pressure of 80 pounds per square inch was exactly 1° Fahr.

Other experiments demonstrated that the wells A and B registered the correct temperature of steam at atmospheric pressure.

The experiments just described proved that a well 3 inches deep indicated the correct temperature of the steam. The next step was to compare wells of different depths.

The wells compared were those in the reservoir A, Fig. 1. Two special thermometers were made in which the reading for steam at 80 pounds pressure, of saturated steam, would be about 1¾ inches from the bottom of the bulb, and which could be easily read to one-quarter of a degree Fahr. This allowed all the mercury in the stems to be heated when the thermometers were placed in short wells.

The two special thermometers were placed in an air oven, together with a thermometer in which the reading for 80 pounds steam pressure was 16½ inches from the bottom of the bulb, and the relative readings of the three thermometers were determined.

The short thermometers were then placed in mercury wells 1¾ and 2½ inches deep, which projected ¾ and 1½ inches, respectively, into the steam space, and the long thermometer was placed in a deep well, so that all the mercury in the stem was heated.

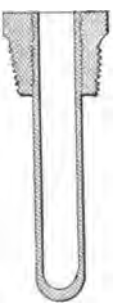
The relative readings for one of the short special thermometers placed in the well, which projected 1½ inches into the steam space

and of the long thermometer when submerged in the deep well were the same for 80 pounds pressure of saturated steam as the readings when uniformly heated to the same temperature in the air oven; which proved that the 1½-inch well and the deep well indicated the same temperature. The well which projected three-quarters of an inch into the steam space indicated between one-eighth and one-quarter of a degree Fahr. lower than the deep mercury well.

It therefore follows that wells of the pattern used in the tests will indicate the true temperatures with saturated steam, provided they project 1½ inches into the steam space.

The wells were made from ⅜-inch steam pipe, the lower ends being closed by welding, and the tops screwed into ¾-inch bushings, as shown in Fig. 3.

Fig. 3.



The air oven, in which the short special thermometers were compared with a long thermometer, was provided with a glass window, through which the thermometers could be read. The bulbs of the thermometers were placed side by side. Other thermometers were placed in the oven with their bulbs in contact with the stem of the long thermometer, in order to prove that the latter was uniformly heated throughout its entire length. Readings were taken at intervals of a minute until the relative indications of the ther-

mometers were constant. The thermometers were then removed from the oven, and their positions changed, after which they were compared a second time. No difference was found, due to change in the position of the thermometers. The air which entered the oven was heated by means of a direct flame of a Bunsen burner. The circulation of air through the oven was considerable and the air was deflected and thoroughly mingled by means of a system of baffle-plates, so that the temperature throughout the oven was very nearly constant.

A second method of comparing wells of different depths was as follows:

A special thermometer was made, in which the reading for saturated steam at 80 pounds pressure was about 18 inches from the bottom of the bulb. The bulb of this thermometer was made large in proportion to the bore of the stem, and the degree marks were about half an inch apart. The stem was graduated to one-tenth of a degree Fahr. The correction, in degrees, for the portion of the stem which is not heated was much smaller in this thermometer than in one of the same length of ordinary construction. The actual amount of the correction for the special thermometer was about one-tenth that for the other thermometers used in the tests, because the one-tenth degree marks on the special thermometer were about the same distance apart as the degree marks on the ordinary thermometers.

The difference in the reading of this thermometer, when placed in a well which projected 2¾ inches in the steam space and when placed in a well 18 inches deep, so that the entire amount of mercury in the steam was heated, was 0.6° Fahr. The theoretical correction, determined by employing the equation which follows, was exactly this amount, and, therefore, the wells were of the same temperature to within the error involved in estimating the average temperature of the portion of the stem of the thermometer which projected above the well. This temperature was measured by means of

two small thermometers, the bulbs of which were placed against the side of the stem projecting above the well. If the error of estimating this temperature had been 10° Fahr., the corresponding difference in the correction, calculated by means of the equation, would have been 0.03 of a degree Fahr., and it is probable that the temperature of the steam was estimated closer than within 10 degrees, so that there could not have been over 0.03 of a degree difference in the short and long mercury well.

The formula for correcting for the portion of the stem which projects above the well is as follows:

$$x = 0.000087\ (t_1 - t_3)\ (t_1 - t_2)$$

in which

x = correction in degrees Fahr.

t_1 = reading of thermometer in degrees Fahr.

t_2 = reading to which the stem is immersed, in degrees Fahr.

t_3 = average temperature of the mercury in the portion of the stem which is not immersed.

0.000087 = factor found by a direct experiment made to determine apparent expansion of mercury in the glass stem of the thermometer, and corrected to allow for variation of the density of mercury at the temperature of the experiment, and the temperature corresponding to the steam pressure of 80 pounds per square inch above the atmosphere.

RELATIVE SENSITIVENESS OF MERCURY THERMOMETER USED IN OIL AND IN MERCURY WELLS FOR MEASURING THE TEMPERATURE OF SATURATED STEAM.

The relative sensitiveness of thermometers when placed in wells containing oil and mercury, which are surrounded by saturated steam, was determined by placing thermometers in the 3-inch wells A and B, Fig. 2. The well A contained oil, and the well B mercury. The thermometers were the same in size and in their graduations.

After performing one set of experiments the oil was removed from the well A and replaced by mercury, and the mercury in B was replaced by oil. The experiments were then repeated. The pressure was maintained constant, as shown by the gauge D, and by observing the temperature registered by the thermometer C. It was found that about seven minutes elapsed before the thermometer placed in the well containing oil would register within one-quarter of a degree Fahr. of the final maximum reading; whereas less than one minute was required for the thermometer placed in the mercury well. The thermometers were cooled to the temperature of the air in the room, which was 80° Fahr., before they were placed in the wells.

Another experiment consisted in varying the pressure of the saturated steam. If the pressure was maintained at 70 pounds per square inch until the readings of the thermometers were constant, and then raised to 80 pounds in one minute, the thermometer in the oil well, instead of showing an increase of temperature of 8° Fahr., as it should have done, provided it correctly registered the increase in temperature of the steam, indicated a rise of only 4° Fahr. The thermometer in the mercury well indicated the correct increase, or 8° Fahr.

ERRORS DUE TO USING OIL INSTEAD OF MERCURY IN THE WELLS.

The thermometer placed in the 3-inch well containing oil, when subjected to a steam pressure of 75 pounds per square inch above the atmosphere, indicated a temperature of about 2 degrees lower than the thermometer placed in the well containing mercury. This was checked by reversing the thermometers in the wells. The difference was caused by the fact that oil is such a poor conductor, compared with mercury, that the heat supplied to the bulb of the thermometer placed in the oil well was insufficient to overcome the effect of the radiation of the stem of the thermometer which projected above the well; whereas with the mercury well there was a

much more rapid conduction of heat to the bulb, and consequently no appreciable error.

If the bulb of the Bristol thermometer be placed in a well containing oil, there will be an error due to conduction and radiation of the heat from the small tube leading to the bulb. When placed in a well 7 inches deep, so that there was 2 inches of oil over the top of the bulb, the error due to this cause was about 1¼° Fahr. The sensitiveness of the Bristol thermometer, in recording rapid changes of temperature, is also greatly impaired when the bulb is placed in a well containing oil. In its present form the bulb of the Bristol thermometer is of brass or copper, and cannot be used in a well containing mercury, so that for accurate work it is advisable to place the bulb in direct contact with the steam.

TESTS OF RELATIVE SENSITIVENESS OF MERCURY THERMOMETERS AND OF THE BRISTOL THERMOMETER WITH SUPERHEATED STEAM.

Tests of relative sensitiveness were also made with superheated steam. To do this, a special throttling calorimeter, similar to the Barrus, was constructed, in which the pipe, into which the superheated steam at low pressure flowed after passing the orifice, was made 2 inches in diameter. This allowed two wells to be placed side by side in the superheated steam, at a distance of about half an inch apart. The orifice of the calorimeter was made of such a diameter that two pounds per minute, or twice the ordinary amount of steam, flowed through the calorimeter. Tests were first made with oil in one of the wells and mercury in the other, a mercury thermometer being placed in each well. After these tests, one well was removed and replaced by the bulb of the Bristol thermometer, and a comparison was made of the Bristol thermometer and a mercury thermometer placed in a well containing mercury. Finally the second well was removed, and the Bristol thermometer

was compared with a mercury thermometer which came in direct contact with the superheated steam.

The calorimeter was supplied with steam drawn from a vertical nipple with no side holes, which projected upward for several inches in a short length of horizontal 4-inch pipe. The pipe was well drained. The steam obtained in this way was found, by previous tests, to be uniformly dry. The steam was led to the calorimeter by a horizontal length of half-inch pipe about 2 feet long, and uncovered. The calorimeter itself was well covered with hair felt.

In making the experiments the calorimeter was first run for about fifteen minutes at a given steam pressure of about 80 pounds per square inch, at the end of which time the readings of the thermometers were constant. Water was then poured slowly on the horizontal length of half-inch pipe leading to the calorimeter, in order to vary the amount of superheating in the steam after passing the orifice, or in some tests a piece of wet waste was placed on the pipe for the same purpose.

It was found that a thermometer placed in a well containing mercury indicated greater changes of temperature, and responded much more quickly, than a thermometer placed in a well containing oil. For example, in one test in which the reading of the thermometers in the oil and mercury wells was about 265° Fahr., for uniform conditions, the minimum temperature registered by the thermometer in the mercury well, after applying water to the pipe, was 232° Fahr., and for the thermometer in the oil well 244° Fahr. Similar figures for other tests were: Mercury well 219 degrees, oil well 236 degrees; and mercury well 221 degrees, oil well 239° Fahr.

The thermometer in the oil well continued to indicate a decrease of temperature after the thermometer in the mercury well had attained the lowest temperature. The temperature registered by the thermometer in the oil well was considerably in excess of that registered by the thermometer in the mercury well at the time the minimum temperature was registered by the latter. For example,

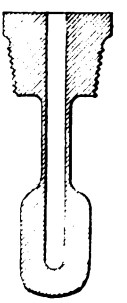
in the case of the tests just given, when the thermometer in the mercury well registered 232, 219, and 221 degrees, the thermometer in the oil well registered 255, 241, and 250 degrees Fahr.

The Bristol thermometer, with the bulb in direct contact with the superheated steam, was found to respond more quickly than a mercury thermometer placed in a well containing mercury, and to be practically of the same sensitiveness as a mercury thermometer placed in direct contact with the steam.

ERRORS IN MEASURING THE TEMPERATURE OF SUPERHEATED STEAM.

There may be a considerable error involved in measuring the temperature of superheated steam by means of mercury wells. For example, in work undertaken some time ago it was necessary to accurately measure the amount of superheating in steam at 80

Fig. 4.



pounds per square inch above the atmosphere, flowing through a 3-inch main at a velocity of 50 feet per second.* To do this, a 6-inch drum, about 1 foot long, was placed in the 3-inch main, and two mercury wells, 4 inches deep, were placed in this drum. One of the wells was made of ⅜-inch standard pipe, as shown in Fig. 3. and the other was made with an enlarged bulb, as shown in Fig. 4, The mercury well with the enlarged bulb indicated a temperature

*See paper on Results of Measurements to Test the Accuracy of Small Throttling Calorimeters. *Transactions*, A. S. M. E., Vol. XVI., page 451.

about 4 degrees higher than the well of the ordinary form. This difference was not found in the case of saturated steam, and in other cases as great a difference has not been found with superheated steam. It is possible to have water running along the bottom, or clinging to the sides of a pipe, while the steam in the pipe is superheated. This was the case with the 3-inch pipe already mentioned, where, with the thermometers indicating 10 or 15 degrees of superheating, water could be drawn from a drip leading

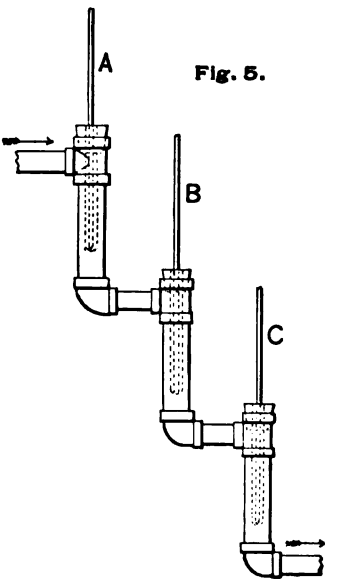


Fig. 5.

from the lower part of the 6-inch drum. The difference of 4 degrees in the results obtained with the two wells was obtained with about 30° Fahr. of superheating, and no water dripping from the drum. The pipe and drum were well covered with hair felt.

Another experiment to show how errors may occur in the measurement of temperatures of superheated steam, was made with the apparatus shown in Fig. 5. Three mercury wells were connected together so that steam passed around and downward past each in succession. Superheated steam at 65 pounds pressure per square

inch above the atmosphere passed through the piping and around the mercury wells at the rate of about one pound per minute. The vertical nipples surrounding the mercury wells were of 1-inch standard pipe, and the horizontal nipples of half-inch standard pipe. In the first tests the mercury wells at A and C were of brass, of the form used by Mr. Barrus in his calorimeter, and the well B was of ¼-inch standard iron pipe. The brass wells at A and C were 4 inches long, projecting 3 inches into the steam space, and the iron well at B was about 3 inches long. The apparatus was thoroughly covered with hair felt. The steam was superheated in different tests from 5° to 20° Fahr. Readings were taken at intervals of 2½ minutes for an hour or more, after which the positions of the wells were interchanged and another set of readings taken. An iron well, 4 inches long, was also compared with the brass wells. Before starting to take the readings with superheated steam the indications of the thermometers were recorded with saturated steam, at 65 pounds pressure, flowing through the apparatus, and the increase of the readings of the thermometers gave the number of degrees of superheating. The tests with saturated steam were also made after each set of readings with superheated steam. The tests showed that the thermometer in the 3-inch iron well at B indicated 3 degrees less superheating than when placed in a brass well at B, when the total amount of superheating as indicated by a thermometer in a brass mercury well at A was 8° Fahr. With 15 degrees superheating at A, the 3-inch iron well gave 2 degrees less superheating at B than the brass well at B.

The 4-inch iron well indicated 1 degree less superheating than the brass well when placed at A.

The results of these experiments are in line with numerous other observations which have been made for measuring the temperature of superheated steam.

The above discrepancies are not found in the case of saturated steam, as has been already explained.

NUMERICAL RELATION OF GRADUATES TO ENTERING STUDENTS IN THE STEVENS INSTITUTE OF TECHNOLOGY FROM 1871 TO 1895.

In connection with various remarks which have been recently made in the public prints concerning the relation between the numbers of students entering and graduating from the Stevens Institute of Technology, it occurred to the writer that some facts of interest might be developed by a presentation in compact or tabular form of the statistics on this subject derivable from a complete set of our catalogues from 1871 to the present year.

Thanks to Prof. Riesenberger, the accompanying table has been prepared and furnishes many interesting indications if studied with a knowledge of the conditions under which the educational work of the Institute was inaugurated, and those under which it has been carried on.

The facts which give special significance to the figures in the accompanying table are the following:

Designation of Class.	Entered.	Numbers in the Same Class in Successive Years.				Per Cent. of Graduates to those Ent'r'g	Accessions to Advanced Classes.	Per Cent. of Graduates, Excluding Accessions.	Entered from Stevens Sch'l.
		Freshmen.	Sophomores.	Juniors.	Seniors.				
'73	1871	.....	.....	2	4	.....	.....	.....	.... ..
'74	1871	.....	3	3	3	.....	.....	.....	... ...
'75	1871	16	15	15	9	56.4	2	43.2	.....
'76	1872	27	19	19	17	59 2	4	44.4	.....
'77	1873	24	8	8	11	41.7	3	29.1	6
'78	1874	40	34	27	22	55 0	2	50 0	9
'79	1875	29	20	17	15	51 2	3	41.1	6
'80	1876	21	14	11	9	38.1	1	33 3	6
'81	1877	36	26	21	19	41.7	4	30.6	11
'82	1878	24	19	14	12	50.0	3	37.1	5
'83	1879	25	19	20	19	76.0	9	40 0	6
'84	1880	48	47	42	41	85.2	14	56.1	13
'85	1881	53	43	42	36	67.5	9	50 5	11
'86	1882	48	37	36	33	66 7	8	50 0	12
'87	1883	58	44	36	30	51.4	4	44 5	11
'88	1884	52	48	42	39	73.1	12	50 0	15
'89	1885	59	44	39	36	61 1	6	50 5	27
'90	1886	58	50	43	39	67.1	7	55.1	24
'91	1887	57	57	49	46	78.9	9	63.2	26
'92	1888	60	50	44	39	65.0	3	60.0	44
'93	1889	66	61	48	43	65.1	3	60 4	49
'94	1890	60	52	51	39	65.0	7	53.2	46
'95	1891	71	61	52	47	63 4	8	52.1	53
'96	1892	109	79	70	63	.....	6	.....	95

When the Institute opened in 1871 we had the following problem to face—i. e.:

To educate in four years, from such material as we could secure from the preparatory schools of the day, young men who, when graduated, should have information enough to make them useful in positions involving some responsibility in the machine shops of the country.

To accomplish this with ease to the student it would have been necessary that he should have been considerably in advance of those entering ordinary colleges in his preparation, so that he might have time during his four years' course, for all the technical studies required to make him a Mechanical Engineer in fact as well as in name.

Students so far prepared, however, were not to be found except in the advanced classes of other colleges, and accordingly we were obliged to compromise matters and place our requirements for admission low enough to let in the best graduates of preparatory schools, and then do our best to carry these imperfectly prepared students through the requisite curriculum.

The result of this, as might be expected, was that many dropped out and our percentage of graduates was low. For example, in 1877, the graduating class represented but 29 per cent. of those entering in 1873. It is, however, interesting to notice that every one of those who survived this severe struggle for existence has shown himself to be a man of exceptional ability in his professional career.

As time went on. however, a constant pressure was kept up in the direction of raising the standard of requirements for admission, and this was most effectively done by the establishment of the Stevens School as a Preparatory Department, in which students might be adequately prepared for admission to the Institute course as well as for colleges giving classical courses.

Time was of course required both for the preparation of students entering the Stevens School and for the growth of its reputation so that the number coming from it should constitute a sufficient proportion of our class to show its effect. Thus, though the school was opened in 1873, it was not until 1880 that it furnished a notable proportion of our entering class. In that year it sent us thirteen students, and the result at once appeared in the rise of the percentage of graduates from 40 per cent. to 56 per cent.

Again, in 1887, a fresh impulse was given to the work of the Stevens School by the erection of a new building for its accommodation which enabled it to increase its own numbers and thus to furnish us with a larger proportion of entering students. The effect of this was seen in 1888, when we received 44 from the Stevens School and our percentage of graduates rose to 60 per cent. from about 50 per cent.

Of course there are many other reasons besides a failure to keep up with the studies of the course which withdraw students from a class prior to graduation. Sickness, change of residence, financial conditions, and sometimes tempting offers of employment have withdrawn many able and promising students before they reached the end of the course, but as the statistics show, and as I know from numerous individual instances, the controlling element is an adequate preparation, combined of course with a reasonable concentration of effort and avoidance of bad influences.

It is not necessary that a young man should be a genius to make a successful engineer. I could point out among our graduates many who were by no means brilliant scholars, but who were well prepared and faithful to their work, who are now occupying such positions as should satisfy the ambition of any reasonable man.

There are a few other points which it may be worth while to notice. For example, the class of '95 entered in 1891, 71 strong, and at the end of their first year had lost but 10 of their number, say 14 per cent., while the next class, that of '96, entering 109 in number, lost in the first year 30, or more than 27 per cent., in other words, nearly a double percentage.

The reason of this is not far to seek if the facts are known.

In 1891, the applicants for admission numbered over 100, but our accommodation being limited, oniy the best among the applicants were admitted and more than 30 were rejected, among whom were many who were sufficiently prepared to have been admitted had there been room.

In 1892, arrangements had been made to divide the classes into two sections and thus double our accommodation; as a result of this, of the 130 who applied and were examined all were admitted who fairly met the requirements, and there was no such preliminary sifting as had been necessary in 1891

The sifting in the first year, however, brought the class of '96 into the same condition of efficiency as the class of '95, and after this the losses were substantially alike in each.

During the first ten years of the Institute there were considerable and irregular fluctuations in the average ratios of graduates and also in the actual number of students, but these fluctuations do not afford any sound basis for deduction because they resulted in part from the small number, which gave a high proportionate value to small accidental variations, and because during this period the Institute was in a formative state as to its requirements, course, and the reputation by which desirable students were attracted. What the figures of this period do show when compared with those of later years is that there has been a decided improvement in the proportion of "finished product" to "raw material," and this in spite of the fact that in consequence of the large number of Engineering Schools established during this quarter-century, we no longer draw so many especially able students from distant points throughout the country. H. M.

OCCUPATIONS OF GRADUATES OF THE STEVENS INSTITUTE OF TECHNOLOGY.

The *New York Sun* of November 17, 1895, commented editorially upon the business success of the graduates of the civil engineering department of Cornell University, and based its statements upon an analysis of the statistics furnished by Professor Fuertes, giving a classification of the various occupations of the graduates receiving the degree of Civil Engineer in that University.

The writer of the editorial also expressed a desire to obtain statistics of a similar character from other schools of engineering, and as a result the Director of the Rensselaer Polytechnic, the President of the Massachusetts Institute of Technology, and the President of the Stevens Institute of Technology, availed themselves of the opportunity to furnish this information regarding the graduates of their respective institutions.

The several records showing that a large number of responsible positions in the various fields of engineering were held by the men who had pursued courses of studies in these institutions were very creditable and satisfactory.

To the readers of the INDICATOR the following statistics, relating to graduates of the Stevens Institute, which were furnished to the *Sun* by President Morton, will be of special interest.

This is a record of the 551 men who graduated from the Institute since its organization and previous to 1895, and of which the editorial observes "is another remarkable record, one worthy of the Stevens Institute and of its learned President who, in his letter to us, speaks of it in moderation and with the utmost modesty."

The classification is as follows:

"Superintendents and managers of the entire business of important departments of machine shops and like engineering works, 148.

"Consulting engineers, carrying on professional work on their own account, 54.

"Professors in technical or engineering colleges or schools, 30.

"Assistant engineers or superintendents in workshops and like mechanical establishments, 55.

"Presidents, vice-presidents, secretaries, and treasurers of manufacturing companies, 16.

"Employed in designing, drawing, and superintending construction of machinery, 103.

"Patent lawyers and solicitors, agents, and inspectors for manufacturing companies, 36.

"Superintendents of motive power on important railroads, 8.

"In employ of foreign corporations, 13. Editors of engineering journals, 6; architects, 3; chemists, 4. Unknown or not classified, 50. Deceased, 25. Among the unclassified should be mentioned an artist who has been for some years *hors concours* at the French Academy, and known all over the world, but who graduated from Stevens in 1876, Mr. Eugene L. Vail."

THE "LINK" AND PRESIDENT MORTON'S OFFER.

We learn with regret that the Board of Editors of the *Link*, under instruction from their several Fraternities, have declined the liberal offer of President Morton to assume the entire financial responsibility of its publication, on condition that they would agree to have it brought out in the style of an ordinary book in which the literary and artistic matter should be the prominent feature, in place of making it, as heretofore for many years, conspicuous as a combination of directory and advertising album.

The reasons assigned for this action on the part of the Board of Editors are in substance a doubt as to their ability to secure literary material adequate to the requirements of a book which might be read and not merely looked at, and, secondly, an unwillingness to sacrifice what they consider their proud preeminence as publishers of the largest, most costly, and conspicuous combination of paper, print, and binding to be found among the college annuals.

Of course, while these sentiments prevail a reform cannot be expected, but we understand that President Morton has announced his intention of keeping his offer open for next year's Annual, and we hope that during the interval the matter will receive further consideration and more judicious views be developed.

As to the ability of the students to collect creditable literary and artistic material we do not entertain the least doubt, while as to the supposed loss of credit in giving up extravagant expense in size, paper, and binding, we agree with President Morton where he says that this is only "an inconsiderate following of a foolish fashion, in which to excel is only to be the leader of the unwise."

The following extracts will give a fair view of the way in which the subject has been so far presented:

[N. Y. *Sun*, Nov. 24, 1895.]

HE CONDEMNS "THE LINK."

PRESIDENT MORTON DISAPPROVES THE STEVENS INSTITUTE'S ANNUAL PUBLICATION.

President Morton, of Stevens Institute, has sent a letter to the Board of Editors of the *Link*, the annual publication of the Institute, in which he refuses to allow the book to be dedicated to him this year. His reason for this course is "that considerations of literary merit have been entirely subordinate to claims of typography, paper, and binding, and that the most approved college annual of the present day resembles nothing so much as the advertising volumes one encounters in the parlors of second class hotels, the saloons of steamboats, and like places."

President Morton was seen by a *Sun* reporter at his home yesterday afternoon. When asked concerning the views here quoted he said:

"I think that our college annuals are too much like mere business enterprises, to the great injury of their literary value. The books are practically given away, although a nominal price of $1 is charged. Anybody looking at any of the recent numbers of the *Link* can see that $1 would scarcely pay for the binding. The intention of the editors is, of course, to make the advertising pay for the book in a large measure, but when the final settlement comes there is usually a deficit, which must be made good by individual subscription. Another great objection in the particular case of the *Link* is that much advertising is diverted from the *Indicator*, the regular publication of the Institute, and a journal which is recognized and quoted throughout the scientific schools of this country and Europe."

"What is your idea of a sensible college annual?" asked the reporter.

"Something about this size," replied President Morton, taking from a shelf near at hand an ordinary sized text book measuring about 5 x 8 inches, and containing 150 or 200 pages. "Take a book of that size, fill it with good, bright literary matter, of which there is no dearth in a college of this size, condense the catalogue portion of the present annual, and you would have what I should call a sensible publication.

"I have talked with some of the students and have promised to see them through the financial part of such an experiment, and I sincerely hope that it will be tried. It is a very radical change, I know, and perhaps I am too anxious to try new things, but I feel that in this instance the experiment would succeed."

[The *Engineer*.]

Quite recently Prof. Henry Morton, of Stevens Institute, Hoboken, referred to college annuals, and intimated that they were being diverted from their legitimate sphere of chronicling events of immediate interest to students and friends of the college, and turned into mercantile ventures in which the collecting of advertisements played too large a part. From our andpoint, this is a just criticism of the subject.

INSTITUTE NOTES.

In view of the various suggestions which have been made concerning the recognition in some public way of the twenty-fifth anniversary of the Institute, it is to be remembered that the Institute, as a matter of fact, was opened for the reception of students during the second week of September, 1871, so that its twenty-fifth anniversary would not be reached until the middle of September, 1896.

In consideration of the fact that the season for opening is now later, and also because the weather during September is liable to be unfavorable for large assemblages, it would seem wise to postpone such ceremonies as it would be desirable to carry on until October, when everything would be in running order, and all conditions most favorable. It would, however, also be well to make, in connection with the exercises of Commencement week, some preliminary recognition of the approaching anniversary, and suggestions as to the form this should take will be cordially welcomed.

In its budget of Institute news items, the Hoboken *Observer* of December 12, 1895, referred to the needs of the Institute as follows: "The Institute is sorely troubled from a monetary point of view, cramped for space, and lacking funds to extend its usefulness. But, though the apparatus used is not of the kind that may be admired solely from a sense of the beautiful, it is thoroughly practical, and more like that which the young engineers will be called upon to handle after graduation, when in the practice of their profession, than the brand-new fittings used at millionaire-endowed universities, where money is of little or no object. In practice, cost is one of the first considerations, and the tools used in practice are not of the gold and silver-plated type. As regards the space at their disposal, steps have been taken by the Stevens Alumni to increase this, but as yet the fund provided by them is incomplete and needs some substantial increase."

The Electrical Department, with the assistance of several members of the Senior Class, and of the mechanics of the workshop, utilized the Christmas vacation in remodeling two old railway motors, and have made useful machines of them. One was suitably rewound, and is to be used as a shunt machine; the other was left with a series field, and will be useful as a separately excited, or as a series dynamo, or motor. The maximum capacity of each machine is about 15 horse-power, normal voltage, 500. With the four-pole General Electric railway motor already on hand, these machines form a combination which is very well adapted for illustrating railway work. The shipment of the new two-phase dynamo ordered last June from the Westinghouse Company, and which was to have been deliv-

ered in December, has been delayed, owing to the fact that when completed the machine did not come up to expectations. The company decided to rebuild it, as it is their desire to send the Institute a first-class machine. When delivered, it will be a valuable addition to the equipment of the electrical department, which is particularly in need of more new-style alternating-current apparatus.

The money remaining in the fund raised by the Class of '95, and with which was purchased the new 30 horse-power engine now supplying power to the dynamo-room, will partly pay for this new machine.

A standard of self-induction, value $\frac{1}{10}$ henry, for which the data used was deduced from the formulæ of Maxwell and Stefan, was also constructed.

The small room north of the electrical laboratory is conveniently fitted up for magnetic measurements. There is no iron in it, the gas and steam pipes being of brass. The determination of curves of hysteresis and permeability, which now forms a part of the regular course of instruction, can readily be made in this room.

About 15 members of the Class of '96 have subscribed $10 each toward the purchase of additional apparatus. In this way, as well as by close application to their work, the students manifest their interest in the course in electricity, and it is hoped that the present excellent course in this department will be still further extended.

THE *Railroad Gazette*, IN ITS ISSUE of December 27, 1895, published the report of an investigation made by Prof. W. H. Chandler, of Lehigh University, and Prof. J. E. Denton for Col. R. H. Wilbur, General Superintendent, Lehigh Valley Railroad, upon an investigation of lamps and gases for car lighting.

The tests were made to ascertain the illuminating powers of the Pintsch Argand and the Gordon-Mitchell Argand lamps when used with compressed Pintsch gas and compressed city water gas.

PROFESSOR KROEH'S BOOKS on "How to Think in French, German, and Spanish" are exciting considerable attention in the educational world. They have been adopted in a number of schools and colleges. Classes have recently been formed in How to Think in German in Oberlin College and Johns Hopkins University. Hon. Lewis Baker, United States Minister to Nicaragua, etc., considers How to Think in Spanish the best book out for learning to speak Spanish.

PROFESSOR MAYER contributed an article entitled "Recherches d'Acoustique" to the *Journal de Physique*, Vol. 4, December, 1895. *The American Journal of Science* for January, 1896, contains an article by the same author entitled "Notes on the Analysis of Contrast Colors, by Viewing Through a Reflecting Tube, a Graded Series of Gray Discs, or Rings, on Colored Surfaces."

PROFESSOR LEEDS has been elected a member of the Executive Committee of the American Chemical Society, for 1896.

AMONG THE PAPERS presented at the New York meeting of the American Society of Mechanical Engineers, held in December, 1895, was one by Professor Denton on "The Reliability of Throttling Calorimeters," and one by Professor Jacobus on an "Experimental Method of Determining the Effective Centre of the Light Emitted from a Standard Photometric Burner."

An abstract of the former paper is published in the *Engineering Record*, December 14, 1895, and the latter paper appeared in *Engineering News*, December 12, 1895. *American Gas Light Journal*, December 16, 1895, and in *Progressive Age*, for December, 1895.

A SPECIAL MEETING of the Executive Committee of the Alumni Association was held at the "Arena," Thirty-first Street, near Broadway, New York City, on Monday, December 2, 1895.

The meeting was called to take action upon the resignation of Mr. P. E. Raqué as Cor Secretary, and to transact such other business as might be introduced. The members present were: Alumni Trustee, Durand Woodman, the officers, H. de B. Parsons, J. H. Lieb, Jr., Robert C. Oliphant, P. E. Raqué, J. Day Flack, William H. Bristol, and the Directors, A. Riesenberger, Harry Van Atta, Arthur de Bonneville, and Kenneth Torrance.

The resignation of Mr. Raqué was accepted with regret. Mr. F. D. Furman, '93, was elected to fill Mr. Raqué's unexpired term.

Professor Graydon's resignation as Editor of the INDICATOR was then considered, and, it having been reported that his Institute duties prevented hi n from issuing the INDICATOR regularly, the committee upon motion decided to accept his resignation. Mr. Durand Woodman, '80, was then appointed as Professor Graydon's successor.

A committee was appointed consisting of Harry Van Atta, Kenneth Torrance, and Adam Riesenberger to consider the advisability of consolidating the positions of corresponding secretary, recording secretary, and treasurer with that of Editor of the INDICATOR. The committee is to report at the next meeting of the Executive Committee.

The proposition of the Lodge & Davis Machine Co. to give a nickeled and gold-plated lathe to the technical institution receiving the largest number of votes did not meet with approval.

THE REGULAR MEETING of the Executive Committee of the Alumni Association was held at the "Arena," New York City, on Thursday, January 9, 1896. There were present Messrs. H. de B. Parsons, '84; John W. Lieb, Jr., '80; William H. Bristol, '84; A Riesenberger, '76; Harry Van Atta, '81; F. D. Furman, '93, and J. Day Flack, '87.

The Committee on Consolidation of the Offices of Corresponding Secretary, Recording Secretary, Treasurer, and Editor of the INDICATOR reported that they did not consider the consolidation of all of these offices feasible and suggested two alternatives; either to combine the offices of Corresponding Secretary, Recording Secretary, and Treasurer, the incumbent to be a member of the Executive Committee, and the Editorship of

the INDICATOR to be a separate office as heretofore, or to combine the offices of Corresponding Secretary and Treasurer in one office and the Recording Secretaryship and the Editorship of the INDICATOR in another, both incumbents to be members of the Executive Committee. The first of these offices, in either case, to receive a salary of $50 per year, and the compensation of the Editor of the INDICATOR to remain, as heretofore, $200 per annum.

The report was received, but no action taken upon it. The Committee on the General Improvement of the Institute reported having held several meetings and having conferred with President Morton. The proposition of Mr. Parsons that a course of lectures on "Banking," "Patent Law," "Specifications," etc, be provided had been under consideration by President Morton, and that such a course of lectures would soon be arranged.

The Corresponding Secretary was instructed to notify the Alumni of the dates and subjects of these lectures, and to extend an invitation to them to attend.

Mr. Durand Woodman's resignation as Editor of the INDICATOR was accepted, and Thos. B. Stillman and A. Riesenberger were appointed co-Editors to fill the vacancy.

The resignation of Fred. W. Cooke as a member of the Association was presented and accepted.

The action of Treasurer Bristol in transferring $600 from the Beneficiary Fund to the INDICATOR account, to pay bills that were due last June, was ratified.

Mr. Bristol stated that this temporary loan could probably be repaid in June, 1896.

A committee consisting of Messrs. Lieb and Oliphant was appointed to audit the Treasurer's accounts and his next annual report.

Messrs. Bristol and Furman were appointed a committee to solicit prices for a safe in which to deposit the Association's books and papers.

The Recording Secretary was instructed to furnish to the Editor of the INDICATOR such information regarding the action of the Executive Committee as, in the opinion of the President and Recording Secretary, will be of interest to the Alumni.

It was decided to hold the midwinter meeting on Wednesday evening, February 19, 1896, in the Hall of Stevens School, and Messrs. Bristol and Furman were appointed a committee to make the necessary arrangements.

The Treasurer reported that a considerable sum of money was due from members in arrears, and that if the members would pay up, the financial condition of the Association would be good.

After some discussion it was decided to insert, each year, in the July issue of the INDICATOR a list of the names of all members who are in arrears for a period of one year or more, provided that the proper notices, as called for by the constitution, shall have been mailed to their addresses, and that they be informed with the last notice that such a list will be published.

A BILL WAS RECENTLY introduced in the United States Senate which provides that: Hereafter all scientific institutions which shall establish a course of engineering satisfactory to the Engineer-in-Chief and to the Secretary of the Navy, shall be permitted to have the graduates taking such a course appointed as cadets in the engineer corps. After having been sent to sea for one year and to an engineering post-graduate school for the same length of time, these civilian appointees are to compete with Naval Academy graduates for commissions in the naval service.

THE ENGINEERING SOCIETY held three meetings during the past term.

On Friday, October 18, Mr. William J. A. Boucher, '96, presented a paper on the "Development of the Power of Niagara." The electrical journals were reviewed by Mr. William H. MacGregor and the mechanical journals by Mr. Charles B. Peck.

At the second meeting, Wednesday, November 12, Professor Woodward, of Columbia College, delivered an interesting lecture on "The Measurement of Base Lines of Precision."

The third meeting was held, Tuesday, December 3. Mr. C. Garcia presented a paper on "Shipbuilding and Design," and Mr. R. T. Kingsford reviewed the mechanical journals.

MR. DURAND WOODMAN, '80, who was appointed Editor of the INDICATOR to succeed Professor Graydon, declined the appointment.

Dr. Stillman and Professor Riesenberger have consented to assume the editorial duties until the Executive Committee again meets, when permanent editors will be elected.

MESSRS. MACMILLAN & CO., of New York, have arranged with Dr. Sevenoak to edit a series of mathematical works for school and college use. The first of the series, a revision of Hall and Knight's Elementary Algebra, has met with such immediate success that a second edition printed from new plates will be issued early in 1896. A Plane and Spherical Trigonometry, with Tables, will be ready for the next school year.

MESSRS. KINGSFORD AND MACGREGOR have chosen as the subject for their thesis "A Test of the Electric Elevators in the Fay Building, New York City," and spent the holiday vacation collecting the necessary data.

INSTITUTE PERSONALS.

'76.

WM. KENT delivered a lecture on "Some Preventable Wastes of Heat in the Generation and Use of Steam," before the Franklin Institute at Philadelphia, Pa. The lecture is published in the December, 1895, issue of the *Journal of the Franklin Institute*.

GUS. C. HENNING delivered a lecture, on January 10, before the New York Section of the American Chemical Society, in which he reviewed the present status of steel analyses.

Mr. Henning, as a member of the Committee on Standard Methods of Testing Materials, made a report, at the December meeting of the American Society of Mechanical Engineers, in New York City, "On the International Convention of Engineers and Manufacturers," held at Zurich, Switzerland, last September.

'77.

MAURICE I. COSTER is in the Chicago office, No. 171 La Salle Street, of the Westinghouse Electric and Manufacturing Company.

'80.

JOHN W. LIEB, JR., is President of the New York Electrical Society.

IN VOL. XII., No. 3, 1895, of the *Proceedings* of the American Gas Light Association, is published a paper written by Alex. C. Humphreys, for the twenty-third annual meeting of that Association, on "The Commercial Value of Photometry." The subject is treated at great length, and an index of the standard works and of the periodical literature on photometry and illumination, referred to in the paper, is appended.

'83.

The Engineering Magazine FOR JANUARY, 1896, contains the paper presented by FREDK. W. TAYLOR at the June meeting of the Amer. Soc. of Mechanical Engineers, held at Detroit, Mich. The editor refers to this paper, which was upon "A Piece-Rate System and Shop Management," as follows: "At that time it attracted much attention and favorable comment. We regard it as one of the most valuable contributions that has ever been given to technical literature, and by reason of that fact, together with the revival of manufacturing activity which has set in, we deem it eminently fitting to accord the paper that distinction which its importance and originality unquestionably merit."

'84.

G. M. SINCLAIR is Secretary and Treasurer of the Philadelphia Machine Tool Co., 445 Garden Street, Philadelphia, Pa.

CHAS. W. WHITING has been advanced from Junior to full membership in the American Society of Mechanical Engineers.

AT THE NEW YORK MEETING of the American Society of Mechanical Engineers, held in December, 1895, H. de B. Parsons presented the report of the Committee on Tests of Fireproof Building Materials. The committee found that under a variation in temperature of 2,000° Fahr., steel beams expand or contract from 1 6 to 1.9 per cent. of their length.

'85.

FRED. N. MORTON, late Superintendent of the Gas Works at Lockport, N. Y., is pursuing a course of instruction in gas analysis under Dr. Stillman.

'88

PAUL DOTY is General Manager of "The Consolidated Gas Company of New Jersey," and is located at 168 Broadway, Long Branch, N. J.

T. A. VAN DER WILLIGEN is connected with the Buffalo Engineering Co., Erie County Savings Bank Building, Buffalo, N. Y., and is at present engaged upon the designs for the proposed shiplifts at Lockport, N. Y.

R. M. BLANKENSHIP, who entered the employ of The Old Dominion Iron and Nail Works Company, Richmond, Va., as its chemist, is now the General Superintendent of the company. These works have been manufacturing terne plates since November, 1895.

'89.

J. C. DANZIGER, formerly connected with the Testing Department of the Bethlehem Iron Co., Bethlehem, Pa., is now established as Mechanical Engineer, at 703 Chamber of Commerce, Detroit, Mich.

'90.

SAMUEL F. SMITH was married to Miss Adelaide Pope, on Wednesday, November 6, 1895.

E. H. PEABODY and Aug A. Goubert presented a paper on "Some Experiments with the Throttling Calorimeter," at the meeting of the American Society of Mechanical Engineers, held in December.

'91.

A. W. ROELKER, partial, is Assistant Superintendent at the Sampling Works of Ricketts & Banks, Marion, N. J.

'92.

J. D. WHITCOMB, who is in the Constructing Division of the General Superintendent's Department of the United Gas Improvement Co., is now located at Kansas City, Mo., with the Kansas City Gas Co.

THE ENGAGEMENT OF Henry C. Meyer, Jr., to Miss Louise Underhill, of Montclair, N. J., has been announced.

'93.

O. G. DALE is designing for the C. W. Hunt Co., builders of coal conveyors and mining machinery, West New Brighton, Staten Island, N. Y.

HERMAN F. CUNTZ is with the Pope Manufacturing Co., Hartford, Conn., as Engineering and General Assistant in the office of the Vice-President and Manager.

W. P. MACKENZIE has been appointed Chief Engineer of the Standard Oil Works at Bayonne, N. J.

C. T. BAYLESS is Associate Editor of the *Railroad Gazette*, Chicago, Ill.

ALVIN BOODY is pursuing a course in assaying of gold and silver ores under Dr. Stillman.

He has been appointed assayer and Assistant Superintendent of the Winnow Gold Mining and Milling Co , Park County, Col., owned and contracted by Boody, McLellan & Co., 57 Broadway, New York City.

ALFRED SIEGFRIED, who took a part of the Institute course, and afterwards pursued a special course in analytical chemistry, has been appointed assayer to the "Argenta" Silver Mining Co., Zacatacas, Mexico.

MAYNARD H. SPEAR, also a partial student, is chemist to the Martin Kalbfleisch Sons' Chemical Works, Bayonne, N. J.

EDWIN R. DOUGLAS is a student in the Graduate School of Harvard University, Cambridge, Mass.

'94.

WINFIELD L. WARNER is in the Mechanical Department of Norton Bros,, Manufacturers of Tin Plate, South Chicago, Ill.

A. M. LOZIER delivered a lecture on the "Practical Manipulation and Care of Dynamos" in the philosophical lecture room of Cooper Union, New York City, on January 19, 1896. This is one of a free course of lectures being given under the auspices of the National Association of Stationary Engineers.

'95.

ARTHUR E. WOOLSEY was married, December 26, to Miss Emily A. Cox. Mr. and Mrs. Woolsey left the following day for Chicago, where they expect to permanently reside, Mr. Woolsey being in the employ of the Illinois Steel Co., at South Chicago.

C. AUSTIN GREENIDGE is with Ernest Flagg, architect, 54 Broad street, New York City.

D. D. BARNUM, E. R. GNADE, C. A. CHURCH and C. T. CHURCH have been elected junior members of the American Society of Mechanical Engineers.

EDGAR BOODY is studying law at the Harvard Law School, Cambridge, Mass.

LIST OF MEMBERS OF THE ALUMNI ASSOCIATION OF STEVENS INSTITUTE.

It is contemplated to publish in the January number of each year a list of the members of the Alumni Association, together with the business address of each.

Care has been taken to make this list as correct as practicable; omissions and errors will be corrected in succeeding lists, if the facts are brought to our notice.

All active members have received the degree of Mechanical Engineer, excepting those whose degrees are stated in foot notes.

Degrees in addition to M. E. conferred upon members are noted after the names of the recipients. Associate members are indicated by the word "Assoc.," following the name, and preceding the date of the class with which the member was identified.

ACKERMAN, WILLIAM S, '91—Consulting Engineer, Nat. Lead Co., 1 Broadway, New York City.

ADAMS, HARRY H., '93—Foreman, Motor Repair Shops, Consolidated Traction Co., Jersey City, N. J.

ADRIANCE, WILLIAM A., '85—Adriance, Platt & Co., Manufacturers of Agricultural Machinery, Poughkeepsie, N. Y.

AGUILERA, ANTONIO JR., '86—With Bernally Sanchez Sugar Co., Porto Principe, Cuba.

ALDEN, JAMES S., '84—Assistant Manager, Brick Factory of L. H. Alden, Passaic, N. J.

ALDRICH, WILLIAM S., '84—Professor of Mechanical Engineering, West Virginia University, Morgantown, W. Va.

ALLAN, PERCY, '95—The Safety Car Heating and Lighting Co., 160 Broadway, New York City.

ANDERSON, LARZ W., '88—Treasurer, J. A. Fay & Egan Co., Cincinnati, O.

ANDERSON, ROBERT M., '87—Assistant Professor of Applied Mathematics, Stevens Institute of Technology.

ANDERSON, ST. GEO. M., '94—Assistant to State Chemist, 103 W. Franklin Street, Richmond, Va.

ANGELL, F. J., '94—Pennsylvania Railroad Shops, Altoona, Pa.

ANTZ, OSCAR, '78—Lake Shore Railway, Brainard Block, Cleveland, O. also Instructor in Mechanical Engineering, The Correspondence School of Technology, Cleveland, O.

ARRISON, P., '95—Thomson Meter Co., Brooklyn, N. Y.

ASPINWALL, JOHN, Assoc , '81—35th Street, cor. First Avenue, New York.

ATKINS, HAROLD B., '92—Roselle, N. J.

ATRISTAIN, ALBERTO, '90—Draughtsman, Mexican Central R. R., Mexico City, Mexico.

ATWATER, C. G , '91—Draughtsman with Solvay Process Co., Coke Oven Dept., Syracuse, N. Y.

AYRES, BROWN,* '78—Professor of Physics, Tulane University of Louisiana, New Orleans, La.

AXFORD, WILLIAM B., '93—W. H. Axford & Son, Heavy Building Contractors and Engineers, 310 Eighth Street, Jersey City, N. J.

BALDWIN, OSCAR, '85—Westinghouse Electric and Manufacturing Co., Pittsburg, Pa.

BALL, B. C , '95—Chief Draughtsman and Designer, with Ball & Wood Engine Co., 470 Morris Avenue, Elizabeth, N. J.

BANG, HENRY A , '88—Benham & Bang, Consulting Mechanical Engineers, 1186 Broadway, New York City.

BARNES, WILLIAM O , '84—Bleckensderfer Manufacturing Co., Stamford, Conn.

BARNUM, D. D., '95—Draughtsman and Chemist, Worcester Gas Light Co., Worcester, Mass.

BATES, JAMES H., '87—Consulting, Contracting, Mechanical, and Electrical Engineer, 126 Liberty Street, New York City.

BAYLES, ROBERT N., '87—81 Fulton Street, New York City.

BAYLESS, C. T., '93—With D. L. Barnes, Consulting Engineer, 1750 Monadnock Building, Chicago, Ill.

BEARD, M. C., '87—Half owner, Ontario Iron Works, Canandaigua, N. Y

BEERS, WILLIAM J., '89—Draughtsman, W. D. Forbes & Co., Engineers, Thirteenth and Hudson Streets, Hoboken, N. J.

BENNS, CHARLES P., '89—Instructor, Providence Manual Training School, Providence, R. I.

BENSEL, JOHN A., '84—Assistant Engineer, Department of Docks, Pier A, North River, New York City.

BEYER, RICHARD, '88—Assistant Engineer, with T. H. McCann, Civil Engineer, Hoboken, N. J.

BIRCHARD, PLINY T., '78—Firm of P. T. Birchard & Co., Railroad Contractors, Marshalltown, Iowa.

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* Received Degree of Doctor of Philosophy.

BLAUVELT, CORNELIUS D., '86—Calumet Gas Co., So. Chicago, Ill.

BOLLER, A. P., JR., '91—Testing Department, H. R. Worthington Hydraulic Works, Brooklyn, N. Y.

BOND, GEORGE M., '80—Manager, Gauge Department, Pratt & Whitney Co., Hartford, Conn.

BONN, HILLRIC J., '78—Weehawken, N. J.

BONNETT, LOUIS B., '89—Editorial Rooms, *N. Y. Tribune*, New York City.

BOODY, ALVIN, '93—With Boody, McLellan & Co., 57 Broadway, New York City.

BOYER, SHIRK, '90—Humphreys & Glasgow, Contracting and Consulting Gas Engineers, 64 Broadway, New York City.

BRAINARD, ALLEN W., '84—Manufacturers' Agent, 41 Dey Street, New York City.

BRAINE, BANCROFT G., '03—With Otis Engineering and Construction Co., 38 Park Row, New York City.

BREWER, SAMUEL B., '76—541 Jefferson Avenue, Elizabeth, N. J.

BRINCKERHOFF, A. G., '77—Mechanical Engineer, Johnson & Morris, Steam and Hot Water Heating, 307-309 West Broadway, New York City.

BRINCKERHOFF, HENRY M., '90—Electrical Engineer, the Metropolitan West Side Elevated R. R. Co., 1313 Monadnock Block, Chicago, Ill.

BRISTOL, B. B., '93—Secretary, The Bristol Co., Waterbury, Conn.

BRISTOL, WILLIAM H., '84—Assistant Professor of Mathematics, Stevens Institute of Technology. President of the Bristol Co., Waterbury Conn.

BROADMEADOW, WILLIAM J., '85—With W. P. Stevenson, 115 Broadway, New York City, and Superintendent, Sea Shore Electric Railway Co., Asbury Park, N. J.

BROOKFIELD, A. B., '93—With Baker & Co., Newark, N. J.

BROOKS, MORGAN, '83—Secretary and Treasurer, Electric Engineering and Supply Co., 413 Jackson Street, St. Paul, Minn.

BROWN, WILLARD, '95—Master Mechanics' Department, Pencoyd Iron Works, Philadelphia, Pa.

BROWN, WILBUR V.,* '80—Assistant Professor of Mathematics and Assistant Director of Observatory, De Pauw University, Greencastle, Ind.

BRÜCK, HENRY T., '78—Master of Machinery, Cumberland and Pennsylvania Railroad, Mt. Savage, Md.

BRUEN, ALBERT E., '93—Inspector, Underwriters' Bureau of the Middle and Southern States, 47 Cedar Street, New York City.

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* Received Degree of Doctor of Philosophy.

BRUEN, G. E., '95—Testing Department, Baldwin Locomotive Works, Philadelphia, Pa.

BUFFETT, E. P., JR., '94—526 Bergen Avenue, Jersey City, N. J.

BURCHARD, ANSON W., '85—Superintendent of Construction, J. M. Ives Company, Danbury, Conn.

BURHORN, EDWIN, '85—Warren & Burhorn, Agents, Stearns Manufacturing Co., 136 Liberty Street, New York City.

BURKE, E. J., '94—Alexandria, Va.

BUSH, S. PRESCOTT, '84—Superintendent of Motive Power, P. C. C. & St. L. R. R., Columbus, O.

BUTTERFIELD, T. E , '95—Student in Civil Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

BUTLER, PIERCE, '82—Mechanical Engineer, Norton Building, Louisville, Ky.

BUVINGER, WILLIAM S., '91—Mechanical Engineer, Engineering Department, Edgar Thomson Steel Works, Bessemer, Pa.

CALISCH, JULIUS, '87—Railway Department, Pennsylvania General Electric Co., Pittsburg Branch, 425 Wood Street, Pittsburg, Pa.

CAMERON, BARTON H., '94—Nortolk and Western R. R. Shops, Radford, Va.

CAMPBELL, GORDON, '88—Purchasing Agent, Consolidated Traction Co., Jersey City, N. J.

CAMPBELL, NORMAN ST. G., '88—Firm of W. D. Forbes & Co., 1300 Hudson Street, Hoboken, N. J.

CARLL, BENJAMIN W., '91—Chrome Steel Works, Brooklyn, N. Y.

CARLTON, WILLIAM N., '90—Mechanical Engineer, 109 White Building, Buffalo, N. Y.

CARROLL, LAFAYETTE D., '84—Mechanical and Electrical Engineer, 10 Union Street, New Orleans, La.

CARTER, L., '95—41 Munn Avenue, East Orange, N. J.

CHANDLER, R. E., '93—Professor of Mechanical Engineering, Agricultural College, Bozeman, Mont.

CHESTER, WILLIAM S., '86—Electrical Engineer and Contractor, C. & C. Electric Motor Co., 143 Liberty Street, New York City.

CHURCH, CHARLES T., '95—Mechanical Engineer, Church & Co., Soda Manufacturers, Trenton, Wayne Co., Mich.

CHURCH, AUSTIN, '95—Mechanical Engineer, Church & Co., Soda Manufacturers, Trenton, Wayne Co., Mich.

CLERK, WILLIAM T., '85—Architect, 32 West Seventeenth Street, New York City.

COFFEY, BARTON H., '85—Mechanical Engineer, The International Contracting Co., Post Building, 12-18 Exchange Place, New York City.

COHEN, F. W., '92—Designing Engineer, Pennsylvania Steel Co., Steelton, Pa.

COLEMAN, H. D., JR., '94—With H. Dudley Coleman & Co., Manufacturers of Plantation Machinery, New Orleans, La.

COLLINS, CHARLES RUSSELL, '86—Inspector of Manufacturing, United Gas Improvement Co., Philadelphia, Pa.

CONNET, F. N., '90—Chief Draughtsman, Builders' Iron Foundry, Providence, R. I.

COOK, EDWIN J., '86—Constructing Engineer, Cleveland General Electric Co., Cleveland, O.

COOK, H. B., '93—B. F. Sturtevant Co., 135 North Third Street, Philadelphia, Pa.

COOKE, JOHN S., '79—President and General Manager, Cooke Locomotive and Machine Co., Paterson, N. J.

COOPER, STEWART, '95—Deane Linseed Oil Co., Port Richmond, S I., N.Y.

CORBETT, L. B., '92—Secretary, South Branch Manufacturing Co., Manufacturers of Chemicals from Wood, Galeton, Potter Co., Pa.

CORBETT, WILLIAM H., '95—Superintendent, Bicycle Department, F. F. Chase Machine Works, Plainfield, N. J.

CORBIN, D., '94—General Electric Co., Schenectady, N. Y.

CORWIN, WILLIAM S., '85—Tucker & Corwin, Consulting and Supervising Engineers, 810 Broad Street, Newark, N. J.

COSTER, MAURICE I., '77—Chicago Office, Westinghouse Electric and Manufacturing Co., 171 La Salle Street, Chicago, Ill.

COTTIER, JOSEPH, '94—12 Congress Street, Jersey City, N. J.

COX, JAMES M., '94—Assistant Superintendent of Terminal Station, Philadelphia and Reading Railroad, Philadelphia, Pa.

COX, JOHN LYMAN, '87—Assistant Forgemaster, Midvale Steel Co., Nicetown, Pa.

COYNE, F. H., '94—10 Arlington Avenue, East Orange, N. J.

CRAFT, MORGAN E., '95—Instructor, Manual Training Department, Montclair Public Schools, Montclair, N. J., and Assistant in Chemistry, Stevens Institute of Technology.

CREMER, JAMES M., '76—Consulting Engineer, 170 Gates Avenue, Brooklyn, N. Y.

CRISFIELD, JAMES A. P., '87—Superintendent (for United Gas Improvement Co.) Savannah Gaslight Co., Savannah, Ga.

CRONISE, ERNEST S., '81—Mechanical Engineer, 17 Broad Street, New York City.

CUMMING, THOMAS B., '95—Worthington Pump Co., 86 Liberty Street, New York City.

CUNTZ, HERMANN F., '93—Engineering and General Assistant to Vice-President and Manager, Pope Manufacturing Co., Hartford, Conn.

CUNTZ, J. H., '87—325 Hudson Street, Hoboken, N. J.

CUNTZ, WILLIAM C., '92—Agent and Engineer, New England Bridge and Construction Department, Pennsylvania Steel Co., Boston, Mass.

DALE, O. G., '93—Draughtsman, C. W. Hunt Co., West New Brighton, Staten Island, N. Y.

DANZIGER, JACOB C., '89—Mechanical Engineer, 703 Chamber of Commerce, Detroit, Mich.

DARBY, JOHN, '91—Wolcott & Darby, Mechanical Engineers, 278½ Main Street, Hartford, Conn.

DASHIELL, WILLIAM W., '79—W. W. Dashiell & Co., Motive Power and Machinery Supplies, 64 Cortlandt Street, New York City.

DAVIS, JESSE A., '91—Office of Engineer of Tests, Mt. Clare Shops, Baltimore and Ohio Railroad, Baltimore, Md.

DEAR, WILLIAM Y., '93—Salesman, Jersey City Printing Co., 37 Montgomery Street, Jersey City, N. J.

DE BONNEVILLE, ARTHUR A., JR., '78—Salesman, The Geo. F. Blake Manufacturing Co., Manufacturers of Steam Pumps, 95 Liberty Street, New York City.

DE GRESS, F. B., '91—Crocker-Wheeler Motor Company, 430 West Fourteenth Street, New York City.

DE LA ROSA, FRANCISCO U., '91—Oaxaca, Mexico.

DE HART, JOHN S., JR., '90—Draughtsman, Isbell-Porter Co., Newark, N. J.

DEMAREST, THOMAS W., '88—Pan Handle Railroad Shops, Columbus, O.

DENT, EDWARD L., '84—Architectural Engineer, Builders' Exchange, Washington, D. C.

DENTON, JAMES E., '75—Professor of Experimental Mechanics, Stevens Institute of Technology.

DICKINSON, G. K., M. D., ASSOC., '75—63 Wayne Street, Jersey City, N. J.

DILWORTH, WILLIAM S., '85—Gordon & Dilworth, 563 Greenwich Street, New York City.

DINKEL, GEORGE, JR., '88—Chief Engineer, F. O. Matthiesen & Wiechers Sugar Refining Co., Jersey City, N. J.

DIX, WALTER S., '87—Draughtsman, Metropolitan Traction Co., New York City.

DIXON, J. ALFRED, '91—Engineer, Pintsch Compressing Co., 160 Broadway, New York City.

DIXON, ROBERT, '81—Manager, Pintsch Compressing Co., 160 Broadway, New York City.

DOTY, PAUL, '88—General Manager, The Consolidated Gas Co. of New Jersey, 168 Broadway, Long Branch, N. J.

DOUGHERTY, WILLIAM M.,* '78—Lawyer, Jersey City, N. J.

DOUGLAS, EDWIN R., '93—54 Hammond Street, Cambridge, Mass.

DOW, ALEXANDER, '91—Dow Type Composing Co., 31 East Seventeenth Street; Mechanical Engineer, 56 Pine Street, New York City.

DREYSPRING, ERNEST, '85—Williamson Iron Co., Birmingham, Ala.

DRUMMOND, EDWIN M., '88—Manager, Drummond Manufacturing Co., Louisville, Ky.

DUCOMMUN, EDWARD, '88—Assistant Engineer, American Sugar Refining Co., Jersey City, N. J.

EASTWOOD, JAMES, '89—Superintendent, B. Eastwood, Foundry and Machine Works, Paterson, N. J.

EBSEN, HENRY L., '89—Draughtsman, Inman and International Steamship Co., Jersey City, N. J.

EBSEN, WILLIAM A., '90—Engineer, The George F. Blake Manufacturing Co., 95 Liberty Street, New York City.

ELLIOTT, THEODORE A., '80—Consulting Mechanical Engineer, Eagle and Adams Streets, Buffalo, N. Y.

ELLSWORTH, OLIVER, '94—Draughtsman with Ingersoll & Sergeant Drill Co., Easton, Pa.

ELSON, LOUIS E., '91—Elson & Brewster Engineering Co., 143 Liberty Street, New York City.

EMMET, C. TEMPLE, '91—New Rochelle, N. Y.

ESTRADA, E. DUQUE, '83—Estrada & Gray, Inspecting Engineers, 307 Lewis Block, Pittsburg, Pa.

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THE VARIATION OF THE MODULUS OF ELASTICITY WITH CHANGE OF TEMPERATURE AS DETERMINED BY THE TRANSVERSE VIBRATION OF BARS AT VARIOUS TEMPERATURES. THE ACOUSTICAL PROPERTIES OF ALUMINUM.*

BY ALFRED M. MAYER.

[Read before the British Association, at Oxford, Aug., 1894.]

[FROM ADVANCE SHEETS]

SUMMARY OF THE RESEARCH.

Poisson in his *Traité de Méchanique* (Paris, 1833, t. II., pp. 368–392)† discusses the laws of the transverse vibrations of a bar free at its ends and supported under its two nodes. He shows that the frequency of the vibrations of the bar is given by an equation, which, reduced to its simplest expression, is $N = V \times 1.0279\frac{t}{l^2}$; in which N is the number of vibrations per second of the bar, t its thickness, l its length, and V the velocity of sound in the direction of the length of the bar.

To ascertain how near the frequency of the transverse vibrations of a bar, computed by Poisson's formula, agrees with the result obtained by experiment, the following method of experimenting was used.

Rods of steel, aluminum, brass, glass, and of American white-pine (*Pinus strobus*)—substances differing greatly in their moduli

* Being Paper No. 10 of "Researches in Acoustics," of the Author.

† See, also, "The Theory of Sound," by Lord Rayleigh, 1894, Vol. I., Ch. 8.

of elasticity, densities, and physical structures—were carefully wrought so as to have the length of 1.5± meter; the thickness of 0.5^{cm}, the width of 2^{cms}, and a uniform section throughout their lengths. The velocity of sound in these rods was determined by vibrating them longitudinally at a temperature of 20°, while held between the thumb and forefinger, and their frequencies of vibration ascertained by the standard forks of Dr. R. Kœnig's tonometer.

Out of each of these long rods were cut three bars of the length of 20^{cms}, and these bars, also at 20°, were supported on threads at their nodes, vibrated transversely by striking them at their center with a rubber hammer, and their frequencies of vibration determined by the forks of the tonometer.

The mean departure of the observed from the computed numbers of transverse vibrations (see Table I.) is $\frac{1}{328}$; the computed frequency being always in excess of the observed, except in the case of glass, where the computed is $\frac{1}{216}$ below the observed frequency.

In Table I., l = length and t = thickness of bar in centimeters at 20°. V = velocity of sound in centimeters in bar at 20°. N = number of vibrations per second at 20°.

The close agreement of the computed and observed values shows that, by vibrating a bar at various temperatures, the variation of its modulus of elasticity with change in its temperature can be obtained. We observe, N, at various temperatures of the bar; then $V = \dfrac{N}{1.0279\frac{t}{l^2}}$ is computed, and the modulus $M = \dfrac{V^2 d}{g}$.

As t, l, and d (the density of the bar), vary with the temperature, the coefficient of expansion of each bar, and its density at 4°, were determined, so that the dimensions and density of the bar could be computed for each of the temperatures at which it was vibrated.

Experiments were made on five bars of different steels, on two of aluminum, on one of St. Gobain glass, one of brass, one of bell-

metal, one of zinc, and one of silver. The results of these experiments may be summed up as follows:

The modulus of elast'y of St. Gobain glass is			1.16	per ct.	less at	100°	than at 0°
"	"	the five steels	" 2.24 to	3.09	"		"
"	"	brass	"	3.73	"		"
"	"	bell-metal	"	4.3	"		"
"	"	aluminum	"	5.5	"		"
"	"	silver	"	2.47	"	60°	"
"	"	zinc	"	6.04	"	62°	"

The decrease of the modulus of elasticity of glass, aluminum, and brass is proportional to the increase of temperature; straight lines referred to co-ordinates giving the results of experiments on these substances. The five steels, silver, and zinc give curves, convex upwards, showing that the modulus decreases more rapidly than the increment of temperature; white bell-metal alone gives a curve which is concave upwards; its modulus decreasing less than the increment of temperature. (See Fig. 5, p. 124.)

The more carbon a steel contains the less is the fall of its modulus of elasticity on elevating the temperature of the steel. Thus, the modulus of the steel with 1.286 per cent. of carbon is 2.24 per cent. less at 100° than at 0°, while the steel containing 0.15 per cent. of carbon has a modulus at 100° which is 3.09 per cent. lower than its modulus at 0°.

So far as experiments on a single steel containing nickel permit of any general deductions, it appears that the presence of nickel in a low carbon steel lowers its modulus of elasticity. Thus, steels Nos. 3 and 4, having respectively 0.47 and 0.51 per cent. of carbon, have a modulus of 2131×10^6, while steel No. 5, containing 0.27 per cent. of carbon and 3 per cent. of nickel, has a modulus of 2050×10^6, which is 2.35 per cent. lower than that of steels Nos. 3 and 4.

The presence of nickel in a steel may, in a diminished degree, have the effect of carbon in lessening the lowering of the modulus

when the temperature of the steel is increased. Thus, the percentage of the lowering of the modulus, by heating from 0° to 100°, of steel No. 5 containing 0.27 of carbon and 3 per cent. of nickel, is the same as that of steel No. 3 with 0.47 per cent. of carbon.

If a bar of any one of the substances experimented on is struck with the same energy of blow, by letting fall on the center of the bar a rather hard rubber ball from a fixed height, the sound emitted by the bar diminishes in intensity and in duration as the temperature of the bar is raised. Thus:

Brass	at 0°	vibrates	dur'g	75	sec.;	at 100°	it vibrates	dur'g 45 sec.
Bell-Metal	"	"		55	"	"	"	40 "
Aluminum	"	"		40	"	"	"	12 "
J. & C. Cast Steel	"	"		80	"	"	"	5 "
Bessemer Steel	"	"		45	"	"	"	1.5 "
St. Gobain Glass	"	"		6	"	"	"	3.5 "

Zinc at 0° vibrated during 5 secs ; at 20° only during 1.5 secs. At 62° it vibrated for so short a time that it only gave three beats with forks of 1090 and 1082 v. s. At 80° it was not possible to determine the pitch of the bar, and at 100° the bar when struck gave the sound of a thud. The bar of silver acted in a similar manner to the bar of zinc—it was even less sonorous than zinc—thus flatly denying the "silvery tones" attributed to it.

These phenomena do not depend on the fall of modulus, but on changes in the structure of the metal on heating, which cause the blow to heat the bar and not to make it vibrate.

Bell-metal was found to be an alloy peculiarly well suited for bells, as the intensity and duration of its vibrations were the same at 50° as at 0°; all other substances showing a marked diminution of intensity and duration of sound at 50°.

A bar of unannealed drawn brass, after it has been heated to 100°, has its modulus at 20° increased $\frac{36}{100}$ per cent. See Table III. and Fig. 11, p. 127.

In this research I had the good fortune to have had the assistance of Dr. Rudolph Kœnig, of Paris. He not only placed at my

service the resources of his laboratory and workshop, but generously gave me constant assistance during the experiments; making the determination of the numbers of vibration of the rods and bars with the standard forks of his tonometer. Without his aid this work could not have been done. For instance, in the cases of the bars of silver and zinc the beats they give with a fork are so few that they cannot be compared with a chronometer; but Dr. Kœnig, from his long experience in the estimation of beats, was enabled to form an accurate judgment of their number per second from the *rhythm* of the beats. The determination of pitches extending through such a range of vibrations as occur in this research can only be made with Dr. Kœnig's "grand tonomètre," a unique apparatus of precision, giving the frequency of vibrations from 32 to 43690 v. s., and really indispensable to the physicist who would engage in precise quantitative work in acoustics.

We now proceed to give accounts of the several operations performed in the progress of this research.

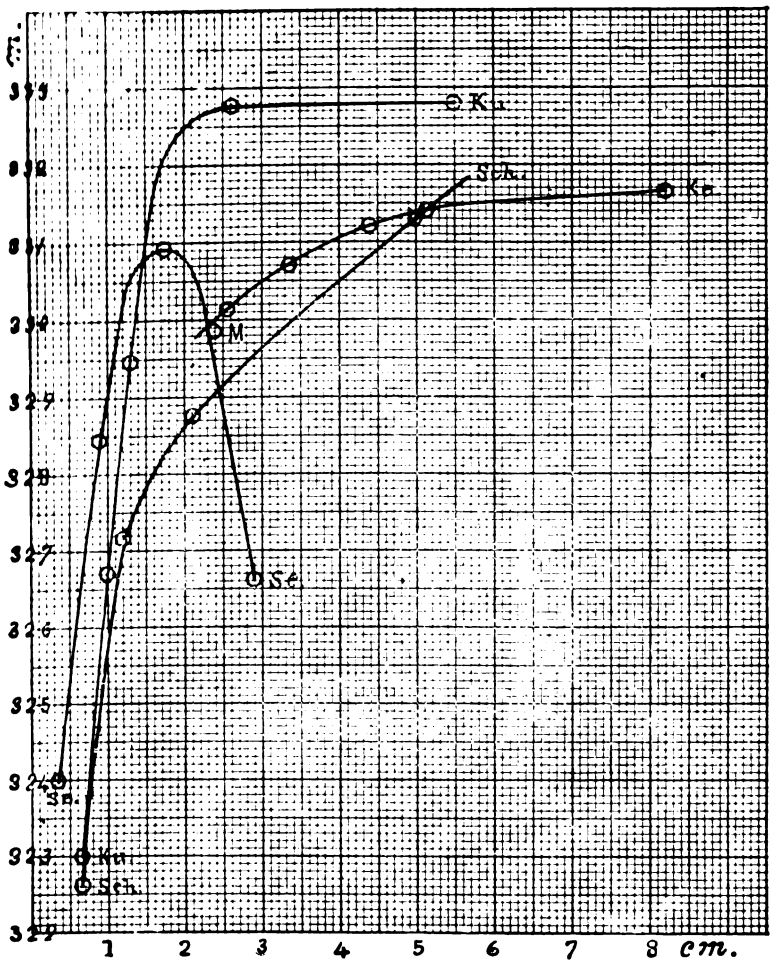
DETERMINATION OF THE VELOCITY OF SOUND IN RODS.

In the determination of the velocity of sound in the rods of 1.5 m. in length I used the method of Chladni.* Kundt's method of obtaining nodal lines of fine powders in a tube, by vibrating a rod whose end carries a cork which fits loosely the end of the tube, is not accurate. The weight and friction of the cork, the necessity of firmly clamping the rod at a node, and, above all, the want of knowledge of the velocity of sound in the air in glass tubes of different diameters, render this method, so beautiful and ingenious, worthless for accurate measures of the velocity of sound in solids.

The curves in Fig. 1 show the very diverse determinations of the velocity of sound in the air in tubes of different diameters by

* Traité d'Acoustique, Paris, 1809. p. 318 *et seq.*

1.



the physicists Kundt†, Schneebeli‡, Seebeck§, and Kayser‖. The velocity of sound in meters is given on the axis of Y; the diameter

† Bericht der Akad. der Wiss zu Berlin, 1867.
‡ Pogg. Ann., 1869, Vol. CXXXVI.
§ Wied. Ann., 1877, Vol II, p 218
‖ Pogg. Ann., 1870, Vol. CXXXIX.

of the tube in centimeters on the axis of X. Ku stands for Kundt, Sch for Schneebeli, Se for Seebeck, and Ke for Kayser. The most precise measures of velocities are those of Kayser, who closed the end of the tube with a cork attached to the end of a steel bar, while the other end of the bar was securely clamped. The frequency of the transverse vibrations of the bar was registered by a style describing the sinusoids of the vibrating bar. Thus the weight and friction of the cork introduced no error. In a similar manner I obtained the velocity, marked M in Fig. 1, by vibrating a rod of aluminum. The frequency of the longitudinal vibrations of the rod were measured while the cork at the end of the rod was vibrating in the mouth of the tube. The result agrees closely with Kayser's. It is needless to discuss the curves of Fig. 1.

The method of Chladni, used exactly as that eminent man used it, remains the best we have. It is important, however, to note that the rod must be held between the thumb and forefinger when it is vibrated and not *clamped* when vibrated. When clamped it always gives a higher frequency, as shown by the following experiments:

Steel rod clamped	3429.2
Steel rod held between fingers	3428.4
Aluminum rod clamped	3377.0
Aluminum rod held between fingers	3376 4

The frequency of the vibrations of the rods of steel, brass, aluminum, glass, and pine wood, when held at the middle of their lengths and vibrated so as to give their fundamental tones, gave exactly the octaves of these fundamental tones when held at one-quarter of their lengths and vibrated.

DETERMINATION OF THE LENGTHS OF THE LONG RODS AND OF THE LENGTHS AND THICKNESSES OF THE BARS.

The lengths of the rods of 1.5± meters were ascertained by comparison with the rod of steel whose length was measured at the Bureau International des Poids et Mesures. The lengths and thick-

nesses of the bars which were vibrated transversely were measured with micrometer calipers. The readings of these calipers were tested by comparison at 20° with a series of standards of various lengths of inches and fractions of inches, made for me with great care by Mr. George M. Bond, who has charge of the gauge department of the Pratt, Whitney Company. In reducing the comparisons to centimeters I adopted the value of the inch as equal to 25.4 millimeters. In obtaining the length of a bar, the mean of several measures in the axis of the bar and in directions parallel to the axis and at various distances from it was adopted. The thickness of a bar was taken as the mean of measures taken throughout the length of the bar at points designated by the intersections of lines drawn parallel and at right angles to the axis of the bar.

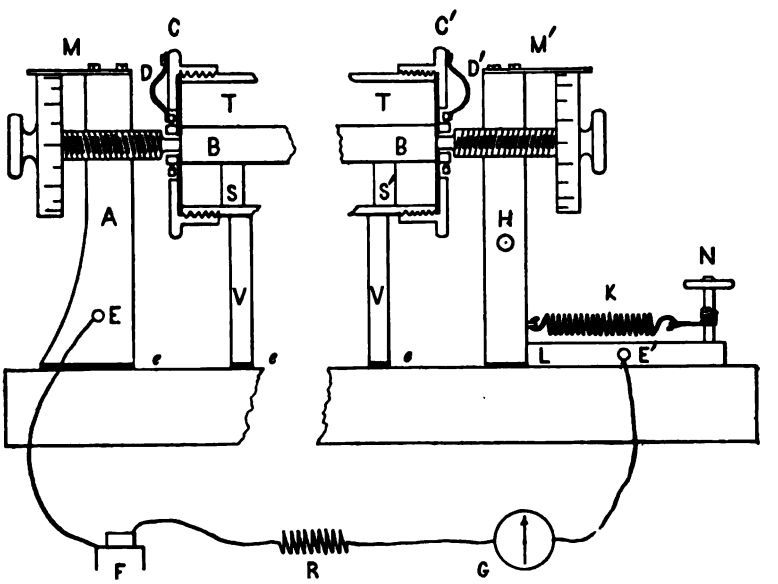
The dimensions of the bars were measured at 20°, except those of steels Nos. 3, 4, 5, which were measured at 18°.25.

DETERMINATION OF THE COEFFICENTS OF EXPANSION OF THE BARS.

To determine the coefficients of expansion of the bars I devised the apparatus shown in Fig. 2. In a brass tube T the bar B rests in slots in the supports S, S′. The tube T is slightly shorter than the bar B. Washers of rubber (shown in black in the figure) of the same diameter as the outside diameter of the tube, are placed in the screw-caps C, C′. These washers are perforated with holes of diameters smaller than the thickness of the bar. When the caps are screwed up the rubber washers press against the ends of the bar. This pressure is further increased by flat rings which surround the holes in the washers and are pressed against these washers by means of the springs D, D′. By this arrangement the surfaces of the ends of the bars are exposed, while the contact of the washers on the bars makes a water and steam tight joint. Thus the bar may be surrounded with ice, or with steam, or with a current of water

of different temperatures, and be cooled or heated up to its terminal planes, while the holes in the washers allow the micrometer screws M, M′ to be brought in contact with the terminal planes of the bar. Two helical springs are attached to the column A. The other ends of these springs are fastened to rods projecting from the tube T. Thus the same pressure of contact is always made between the bar and the end of the micrometer screw M. The

2.



tube T is supported in Vs, V, V′, and the greater part of the weight of the tube is taken off the Vs by helical springs fastened to a frame above the apparatus. The tension of these springs can be so regulated that the tube rests on the Vs with the same pressure when the tube has steam passing through it or when it is filled with ice. The column A and the Vs, V, V′, are insulated from the base of the apparatus by thin plates of ebonite *e*. Between the

binding screws E and E′, and connected by wires, are the voltaic cell F, the galvanometer G, and a box of resistance coils R. The micrometer-screw M′, with which the variations in length of a bar are measured, is mounted as follows: The screw passes through its nut in a massive brass plate with rotates around nicely fitted centers at H. These centers are supported by two side plates not shown in the figure. A spring K is fastened to the lower part of the swinging nut-plate and brings this plate against the plate L, firmly fastened to the base of the apparatus. When the swinging plate is vertical and the axis of the screw horizontal the swinging plate fits accurately the surface of the fixed plate L. By turning the rod N, the swinging plate and its screw can be rotated away from the bar. This arrangement allows the screw to be swung out of the way while the tube T is being placed in the Vs. Also, it prevents any strain between the micrometer-screw M′, and the column A, which would take place if M′ were fixed and it should be brought in contact with a hot bar in the tube T.

With careful manipulation successive electric-contacts can be made on a bar in the tube T, surrounded by ice, so that the variations in a series of measures will not exceed $\frac{1}{000}$ mm., with a resistance of about 200 ohms placed in the circuit.

It may be reasonably objected to this apparatus that when the micrometer-screw touches the bar at 0° it is cooled and shortened, and that when it touches the bar at 100°, or at temperatures higher than that of the screw, the latter is heated and elongated. This error, however, is quite small, and may be neglected in our work. If we assume that 1 centimeter of the screw is heated 10°, which is a large estimate, considering the duration of contact of screw and bar during a measure, the shortening or elongation of 1 cm. of the screw by cooling or heating it 10° amounts to only 0.0012 mm., or $\frac{1}{100000}$ of the length of the bar. This change in the length of the screw will affect the coefficient of expansion of the bars only 0.00000006.

DETERMINATION OF THE DENSITIES OF THE BARS AT 4°.

The bar, whose density was to be determined, was immersed in water at 4° for a couple of hours. The bar was then suspended by a platinum wire in water at 4° and weighed. The bar was then removed from the wire and a quantity of water equal in volume to the volume of the bar was added to the water in the vessel, and the platinum wire, now immersed exactly as it was when the bar was attached to it, was weighed. This weight, subtracted from the previous weighing, gave the weight of the bar in water. Every precaution was taken to prevent, by means of screens, the action on the balance of the currents of cold air in the balance-case, which are produced by the constant descent of air from the sides of the cool vessel.

THE APPARATUS IN WHICH THE BARS WERE HEATED AND COOLED. ON THE PRECAUTIONS USED SO THAT ONE IS SURE OF HAVING THE REAL TEMPERATURE OF THE BAR WHEN IT IS VIBRATED.

The apparatus used to heat and cool the bar is shown in Fig. 3. In a brass box C is inclosed a box C′ containing the bar B supported on its nodes N N by threads held by upright rods. From this central box two tubes T P pass through the outer box C. The inner box is made water-tight and steam-tight by a rubber washer which is pressed between the top of the box and its cover by means of screws. Through the tube T the bar is vibrated by letting fall upon its center a rubber ball fastened to a light wooden rod. On the blow of the ball it rebounds and the rod is caught by the fingers in its upward motion. The cork is then at once replaced in the tube T. The sound from the bar is conveyed to the ear, at E, by means of a tube (Fig. 4). One branch of this bifurcated tube leads through a rubber tube to the pipe P of the box, Fig. 3. The other branch leads to the fork F, the number of whose beats per second made with the vibrating bar is measured by a chronometer. The

pipe S allows the steam to issue when water is boiled in the box C′ by a gas lamp. The flow of gas through this lamp was neatly regulated by a stop-cock turned by a long lever. The box C is covered, except at the bottom, with thick felt.

To determine the frequencies of vibration of a bar through a range of temperature from 0° to 100°, the following method was

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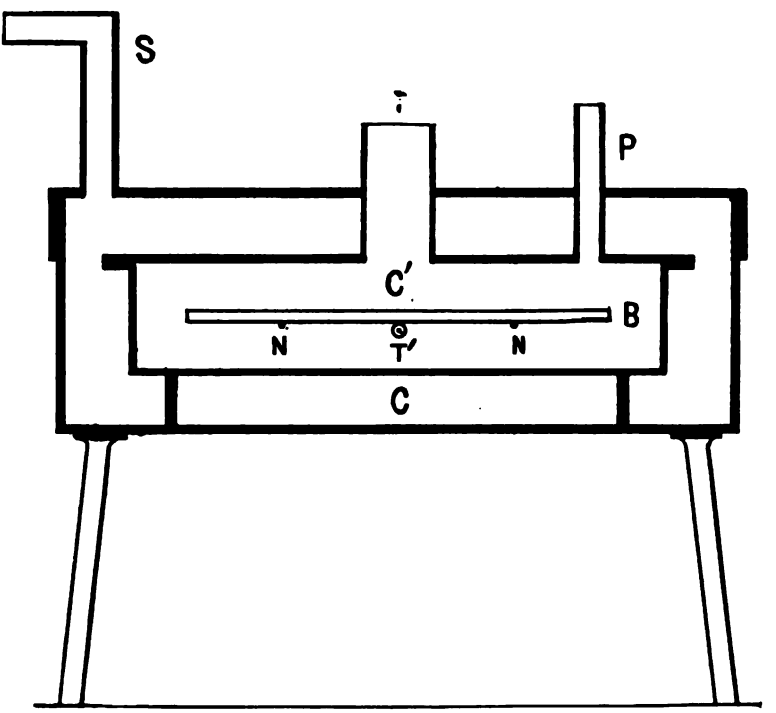
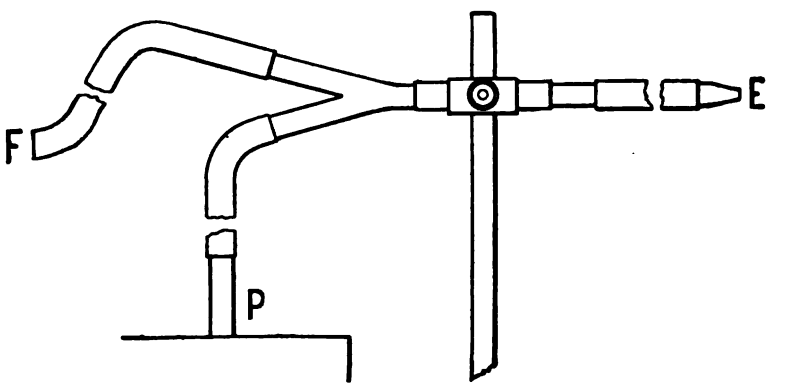


used: The box C was filled with ice, surrounding the inner box C′. It thus remained for an hour, so that the boxes were cooled down to 0′, and the moisture in the inner box has been condensed so far as it can be at 0°. The bar, which has been in ice for two hours, is wiped dry and quickly introduced into the inner box. A thermom-

eter T′ (made by Baudin and corrected), entered the boxes through stuffing-boxes, and whose bulb touched the under surface of the bar, was read until it became stationary. The bar was now vibrated and its frequency of vibration determined for the temperature given by the thermometer.

The lamp was now placed under the box and the water in it boiled till the thermometer reached its maximum reading and the reading remained stationary during a half-hour. The vibration frequency at this temperature was taken. The flame of the lamp

4.



was now lowered and the box allowed to cool very slowly, at the rate of 1° fall of temperature in about eight minutes. When the thermometer read 80°, 60°, 40°, the flame of the lamp was carefully adjusted, so that these successive temperatures were maintained duting 15 minutes. We then took the frequency of vibration of the bar.

The numbers of vibrations of the forks used in the determinations of the pitches of the bars were corrected for temperature by the coefficient 0.0001118, determined by Dr. Kœnig in 1880 (Quelques Experiences d'Acoustique, Paris, 1882, p. 172, *et seq.*).

The subsequent tables show the results of the experiments and give the computations of velocities and moduli founded on them. The curves express graphically the effect of change of temperature on the modulus of elasticity of all the bars experimented on. The circles, on or near the curves, give the data as determined by the experiments.

In Table III., T = temperature of bars, l = the length, t = the thickness, and V = the velocity of sound through the bars, in centimeters. M = the modulus in grams per square centimeter section of the bar. g, at Paris, equals 980.96. D = the density, and N = the number of vibrations of the bar per second at temperature T.

All of the bars were annealed, except those of Jonas and Colver steel, of the French aluminum and of brass; these were experimented on just as they came from the draw-bench.

For the analyses of the substances of the bars experimented on, I am indebted to my colleagues, Professors Leeds and Stillman.

TABLE I.

Bar.	l.	t.	V at 20° =	N Computed by $N = V\,1.0279\,\frac{t}{l^2}$	N Observed at 20°	Diff.
Steel No. 1....	20.022	.5025	150.02 × 3427.4 v. s.	662.49 v. d.	660.8	+ 1.69 = $\frac{1}{391}$
" No. 2....	20.0246	.5037	= 514178^{cms}	663.91 "	661.0	+ 2.91 = $\frac{1}{227}$
" No. 3....	20.0225	.5022		662.07 "	660.3	+ 1.77 = + $\frac{1}{373}$
Aluminum.						
No. 1.....	20.0253	.4993	150.05 × 3377 v. s.	648.51 "	646.6	+ 1.91 = $\frac{1}{339}$
No. 2.....	20.0296	.4991	= 506719^{cms}	647.97 "	647.0	+ 0.97 = $\frac{1}{667}$
No. 3.	20.0233	.4998		649.80 "	648.0	+ 1.8 = $\frac{1}{360}$
Brass.						
No. 1.....	20.02	.50116	150.05 × 2886.4 v. s.	460.23 "	459.0	+ 1.23 = $\frac{1}{373}$
No. 2.....	20.02	.50147	= 358079^{cms}	460.58 "	458.95	+ 1.58 = $\frac{1}{290}$
No. 3.....	20.02	.50108		460.16 "	458.35	+ 1.81 = $\frac{1}{253}$
St. Gobain Glass.....	23.516	.747	152.2 × 3582 v. s. = 538016^{cms}	747.03 "	749.75	− 2.72 = $\frac{1}{275}$
White Pine. Density = .365	41.15	.808	171.18 × 3072.75 v.s. = 525998^{cms}	256.38 "	256.0	+ 0.38 = $\frac{1}{673}$

Mean departure of computed from observed value = $\frac{1}{333}$ of observed value.

TABLE II.

Table of Analyses, of Densities at 4°, and Coefficients of Expansion of Bars.

	Iron.	Carbon.	Silicon.	Phos.	Sulph.	Mang.	Nickel.	Density at 4°	Coef't Expan.
J. & C. Steel	98.259	1.286	0.015	0.059	0.031	0.350	...	7.827	.0000110
No. 3 "	98.738	0.47	0.15	0.022	....	0.62	....	7.848	.0000118
No 4 "	98.628	0.51	0.158	0.024	....	0.68	....	7.845	.0000120
No. 5 "	95.719	0.27	0.101	0.031	....	0.69	3.189	7.851	.0000119
Bess'r "	99.03	0.15	0 02	0.09	0.06	0.65	....	7.841	.0000122

Brass.

Copper	64.34
Zinc	34.97
Lead	.58
Iron	.11
Density	8.476
Coeft. expan	.0000185

Bell-Metal.

Copper	80.08
Tin	18.97
Lead	.12
Zinc	.49
Density	8.348
Coeft. expan	.0000187

Aluminum (Amer.).

Aluminum	98.99
Free Carbon (graphite)	.19
Combined Carbon	.16
Tin	.21
Silicon	.82
Iron	.15
Density	2.702
Coeft. expan	.0000232

Aluminum (French).

Aluminum	97.80
Carbon with Si	.14
" free	.04
" with Copper	.09
Copper	1.29
Silicon	.64
Density	2.730
Coeft. expan	.000022

Silver, Pure.

Density	10.512
Coeft. expan	.0000184

Zinc.

Zinc	.99.75
Iron	.10
Lead	.04
Density	6.8107
Coeft. expan	.0000296

St. Gobain Glass.

Silicon	.72.8
Alumina	.8
Lime	15.8
Soda	11.8
Density	2.545
Coeft. expan	.00000777 (Fizeau)

TABLE III.

Bar.	$T.$	$l.$	$t.$	$\frac{t}{l^2}$	$D.$	$N.$	$V=\frac{N}{1\ 0279\frac{t}{l^2}}$	$M=\frac{l^2 d}{g}$	$M.$
Jonas & Colver Cast Steel.	0.2	20.0207	.5036	.0012564	7.828	662.0	512602	2097585540	2097×10^6
	20	20.0246	.5037	.0012562	7.823	661.0	511908	2089805486	2090×10^6
	40	20.0286	.5038	.0012561	7.818	659.6	510112	2080863837	2081×10^6
	61	20.0328	.5039	.0012560	7.814	658.6	509389	2072936852	2073×10^6
	80	20.0366	.5040	.0012554	7.809	657.1	508470	2064153151	2064×10^6
	99.8	20.0406	.5041	.0012551	7.804	655.14	507065	2050537870	2050×10^6
Steel No. 3.	0	20.3513	.64049	.0015464	7.849	820.38	516124	2131430318	2131×10^6
	18.25	20.3558	.64063	.0015460	7.844	818.91	515329	2123515662	2123×10^6
	34	20.3594	.64074	.0015457	7.8395	817.50	514539	2115797406	2116×10^6
	60	20.3657	.64094	.0015453	7.832	814.70	512907	2100383667	2100×10^6
	80	20.3705	.64109	.0015449	7.8265	812.40	511586	2088031273	2088×10^6
	99.5	20.3752	.64124	.0015446	7.821	810.00	510175	2075047228	2075×10^6
Steel No. 4.	0	20.3517	.64295	.0015523	7.846	824.71	516238	2131556968	2131×10^6
	18.25	20.3562	.64312	.0015520	7.841	822.71	515708	2125826869	2126×10^6
	40	20.3614	.64328	.0015517	7.3345	821.25	514893	2117356581	2117×10^6
	51.5	20.3643	.64337	.0015514	7.831	819.67	514002	2109091886	2109×10^6
	81	20.3715	.64360	.0015508	7.823	816.30	512088	2091259452	2091×10^6
	97.6	20.3755	.64373	.0015505	7.819	814.00	510745	2079256951	2079×10^6
Steel No. 5.	0	20.3513	.64188	.0015498	7.852	813.29	510527	2086250350	$20\ 6 \times 10^6$
	18.25	20.3559	.64202	.0015494	7.847	811.84	509757	2078637463	2078×10^6
	40	20.3609	.64218	.0015490	7.841	809.68	508529	2067052961	2067×10^6
	60	20.3657	.64233	.0015486	7.835	807.31	507168	2054430194	2054×10^6
	80	20.3706	.64248	.0015482	7.829	805.02	505856	2042249532	2042×10^6
	99.5	20.3753	.64264	.0015479	7.824	802.71	504506	2030066264	2030×10^6
Bessemer Steel	0.4	20.451	.60144	.0014380	7.8421	761.37	515093	2121057163	2121×10^6
	20	20.456	.60160	.0014377	7.8364	759.80	514032	2110783287	2111×10^6
	40	20.461	.60176	.0014374	7.8306	757.70	512960	2100440462	2100×10^6
	60	20.466	.60190	.0014370	7.8248	755.41	511409	2086216940	2086×10^6
	80	20.471	.60205	.0014367	7.8192	752.90	509710	2070893085	2071×10^6
	100	20.476	.60220	.0014363	7.8134	749.90	508026	2055702283	2056×10^6
Brass when bar was cooled from 99°.6 to 1°.	1°	22.0128	.5009	.0012506	8.4774	460.64	358337	1109672142	1109×10^6
	21.8	22.0208	.5011	.0012501	8.4677	458.95	357307	1102010322	1102×10^6
	40	22.0274	.50126	.0012497	8.4592	457.40	356103	1093479554	1093×10^6
	60	22.0348	.50144	.0012492	8.4498	455.70	355052	1085864045	1086×10^6
	80	22.0422	.50162	.0012488	8.4404	454.00	353727	1076578495	1076×10^6
	99.6	22.0494	.50180	.0012483	8.4312	452.30	352678	1069044150	1069×10^6
Brass before bar was heated to 99°.6.	0.4	20.0127	.5008	.0012504	8.4778	460.04	357928	1107191685	1107×10^6
	20	20.0208	.5011	.0012501	8.4685	458.35	356698	1098388907	1098×10^6
Bell-Metal.	0	22.2402	.82054	.0016589	8.3490	572.05	335300	956864118	956.8×10^6
	21	22.2490	.82114	.0016588	8.3390	569.50	333806	947214927	$947\ 2 \times 10^6$
	40	22.2568	.82168	.0016587	8.3302	567.12	332411	938324839	938.3×10^6
	50	22.2610	.82196	.0016587	8.3256	566.02	331766	934172231	934.2×10^6
	60	22.2650	.82224	.0016586	8.3208	564.94	331133	930074354	930.1×10^6
	74	22.2780	.82266	.0016586	8.3144	563.61	330354	924989117	$925\ 0 \times 10^6$
	99.75	22.2818	.82338	.0016584	8.3025	561.21	328946	915914824	915.9×10^6

Bar.	T.	l.	t.	$\frac{t}{l^2}$	D.	N.	$V = \frac{N}{1.0279\frac{t}{l^2}}$	$M = \frac{l^3 d}{g}$	M.
Aluminum (American).	0.4	21.612	.55176	.0011813	2.7027	621.00	511423	720621232	720.6 × 10⁶
	20	21.622	.55200	.0011807	2.6990	618.10	509032	712929083	712.9 × 10⁶
	45	21.6346	.55232	.0011800	2.6943	613.90	505993	703215278	703.2 × 10⁶
	60	21.6422	.55250	.0011796	2.6915	611.60	504516	698390198	698.4 × 10⁶
	82	21.654	.55278	.0011789	2.6874	607.88	501447	688868686	688.8 × 10⁶
	99.5	21.662	.55300	.0011785	2.6840	604.71	499247	681974176	681.9 × 10⁶
Aluminum (French)	0.5	20.0170	.49914	.0012457	2.7306	650.00	507632	717306505	713.0 × 10⁶
	20	20.0253	.49930	.0012451	2.7270	646.60	505375	710002959	710.0 × 10⁶
	40	20.0340	.49950	.0012445	2.7232	642.78	502388	700672761	700.6 × 10⁶
	60.5	20.0428	.49965	.0012438	2.7194	639.19	499977	692975831	692.9 × 10⁶
	81	20.0518	.49980	.0012430	2.7156	635.50	497477	685124447	685.1 × 10⁶
	100	20.0600	.50000	.0012425	2.7120	632.00	494734	676700317	676.7 × 10⁶
Silver.	0.3	17.2176	.4614	.0015564	10.5142	437.93	273736	803135399	803.1 × 10⁶
	20	17.2250	.46158	.0015557	10.5022	437.35	273489	800762642	800.7 × 10⁶
	30	17.2284	.46168	.0015554	10.4962	436.80	273201	798729900	798.7 × 10⁶
	40	17.2316	.46176	.0015551	10.4900	435.80	272626	794797589	794.8 × 10⁶
	60	17.2380	.46194	.0015545	10.4778	433.00	270979	783307979	783.3 × 10⁶
Zinc.	0.3	18.2094	.44517	.0013426	6.8130	559.84	405663	1142925404	1143 × 10⁶
	20	18.2200	.44534	.0013415	6.8010	557.84	404501	1134426237	1134 × 10⁶
	40	18.2308	.44552	.0013405	6.7890	553.76	401844	1117556599	1117 × 10⁶
	50.5	18.2364	.44560	.0013399	6.7826	551.22	400294	1107903320	1108 × 10⁶
	62	18.2426	.44570	.0013390	6.7758	548.61	394291	1073843790	1074 × 10⁶
St. Gobain Glass.	0.3	23.496	.74898	.0013566	2.5452	750.65	538313	751865836	751.8 × 10⁶
	24.5	23.501	.74902	.0013562	2.5436	749.67	537769	749885431	749.8 × 10⁶
	40	23.503	.74910	.0013561	2.5424	749.12	537403	748511034	748.5 × 10⁶
	60	23.507	.74922	.0013558	2.5411	748.35	536909	746742620	746.7 × 10⁶
	80	23.510	.74934	.0013557	2.5397	747.62	536497	745196510	745.2 × 10⁶
	99.5	23.514	.74945	.0013554	2.5384	746.70	535955	743311215	743.3 × 10⁶

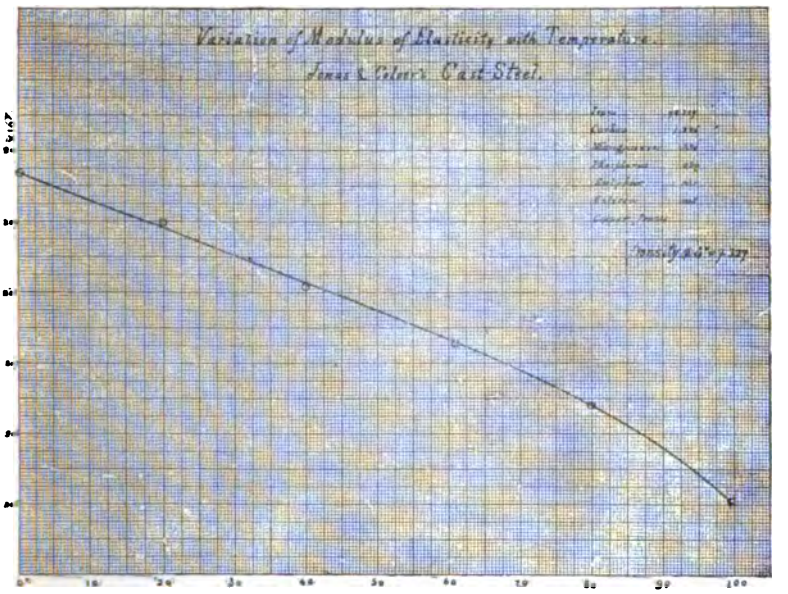
TABLE IV.

Variation of Modulus of Elasticity with Change of Temperature.

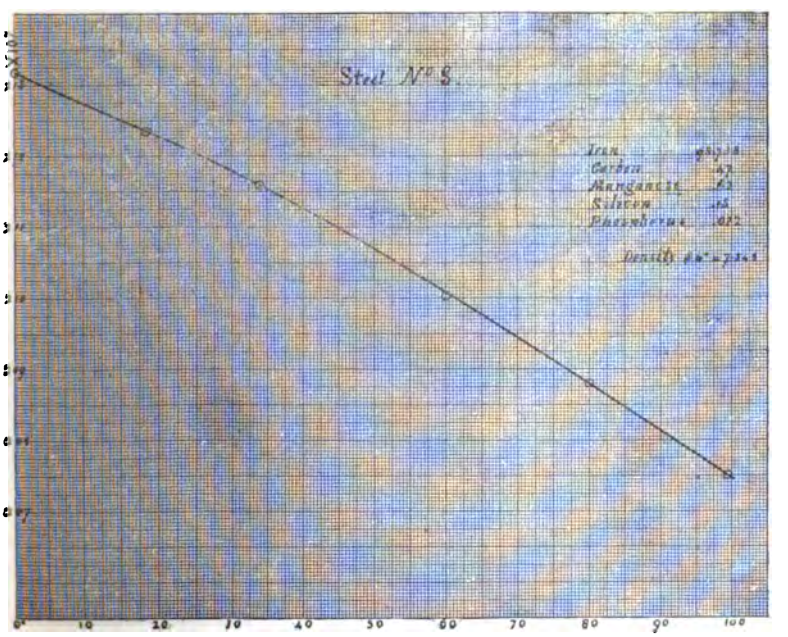
In this table the modulus of each substance is taken as 100 at 0°. In computing this table the moduli taken were those obtained from the curves passing through the mean positions of the points determined by the experiments. The results contained in this table are expressed graphically in Fig. 5.

T.	J. & C. Steel.	Steel No. 3.	Steel No. 4	Steel No. 5.	Bessemer Steel.	Brass.	Bell-Metal.
0°	100.00	100.00	100.00	100.00	100.00	100.00	100.00
20°	99.61	99.57	99.70	99.58	99.53	99.26	99.03
40°	99.25	99.10	99.31	99.10	98.99	98.51	98.09
60°	98.87	98.58	98.8	99.54	98 35	97.76	97.21
80°	98.42	98.00	98.22	97.98	97.63	97.03	96.38
100°	97.76	97.34	97.54	97.35	96.91	96.27	95.70
	Aluminum (Amer.)	Aluminum (French).	Silver.	Zinc.	St. Gob. Glass.		
0°	100.00	100.00	100.00	100.00	100.00		
20°	98.92	98.86	99.73	99.26	99.76		
40°	97.83	97.73	98.97	97.78	99.53		
60°	96.75	96.58	97.53	93.96(62°)	99.30		
80°	95.67	95.42	....	...	99 07		
100°	94.59	94.31	....	....	98.84		

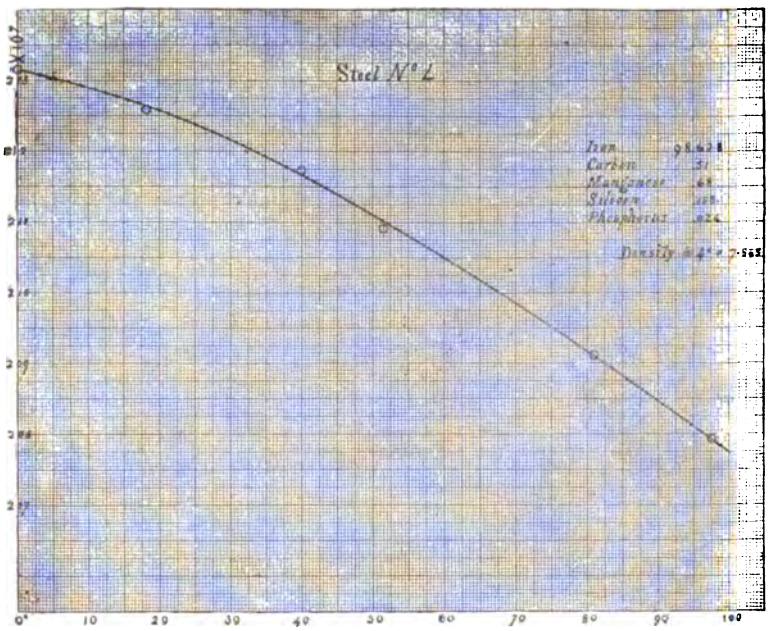
6


Variation of Modulus of Elasticity with Temperature.
Jones's Colours. Cast Steel.

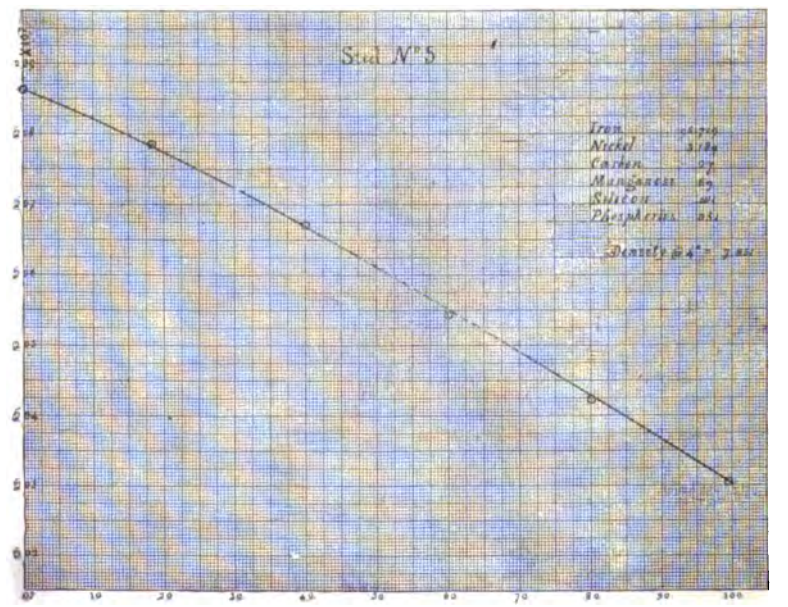
7


Steel N° 8.

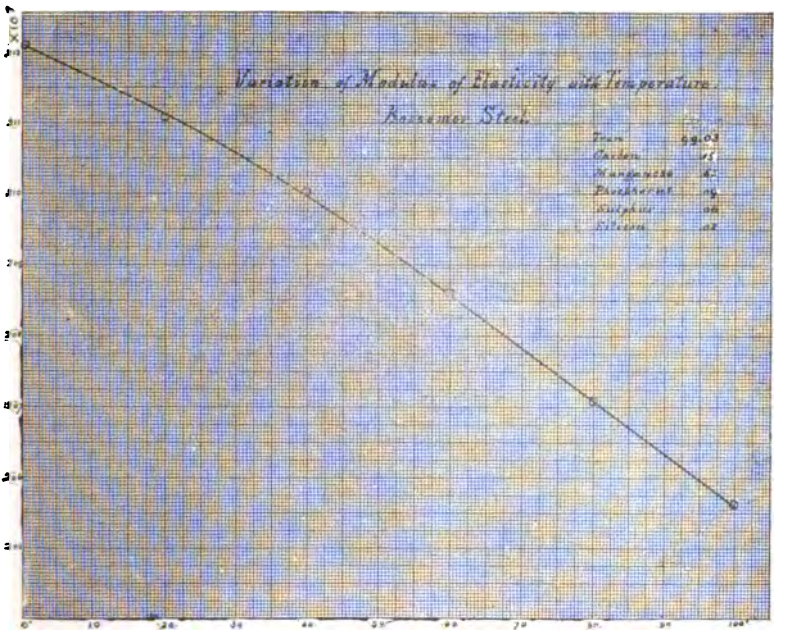
8.


Steel N° 2
Iron
Carbon
Manganese
Silicon
Phosphorus
Density
0°
10
20
30
40
50
60
70
80
90
100

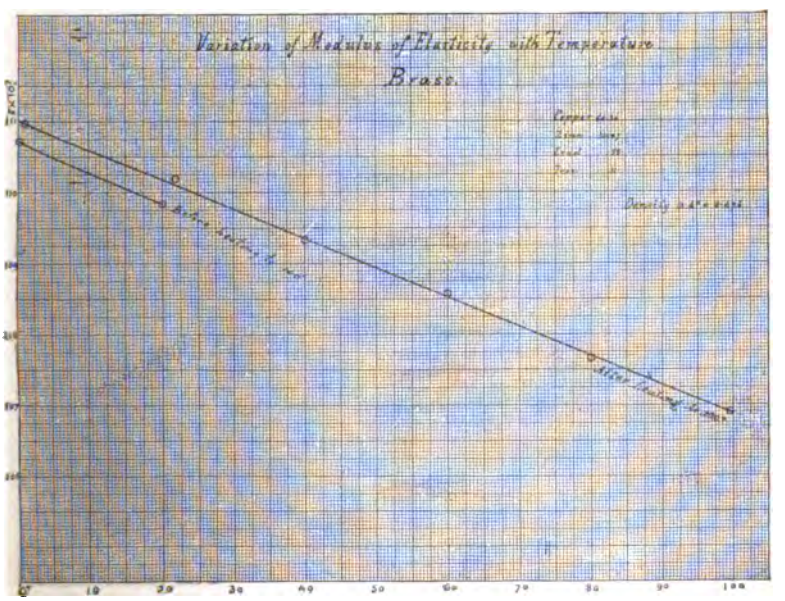
9.


Steel N° 5
Iron
Nickel
Carbon
Manganese
Silicon
Phosphorus
Density

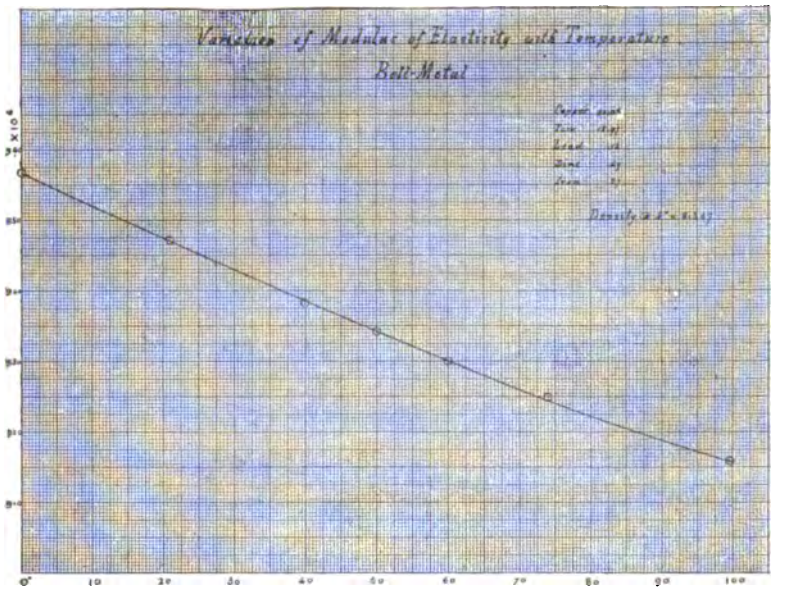
10


Variation of Modulus of Elasticity with Temperature.
Bessemer Steel.

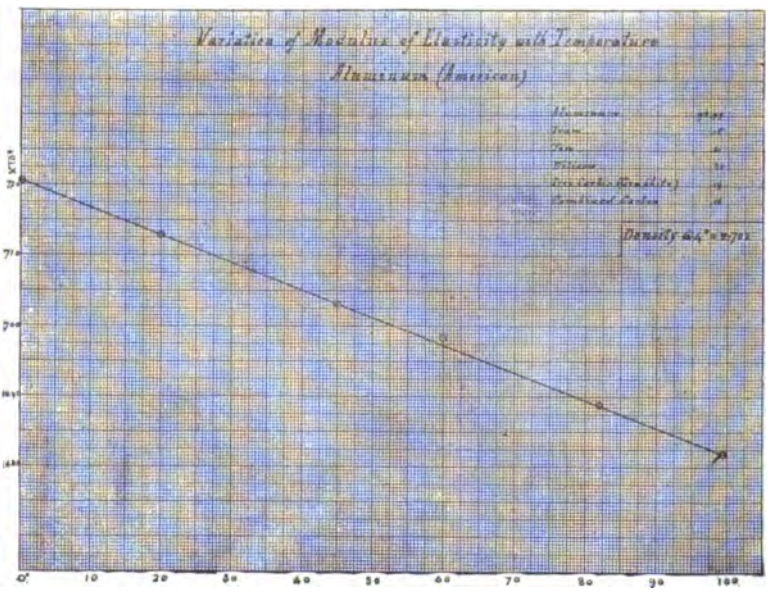
11.


Variation of Modulus of Elasticity with Temperature.
Brass.

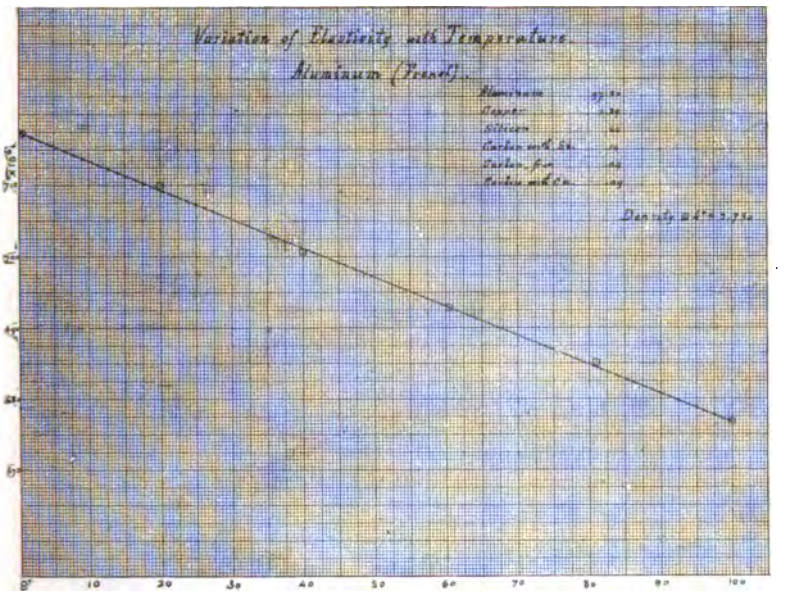
12.


Variation of Modulus of Elasticity with Temperature
Bell-Metal
0° 10 20 30 40 50 60 70 80 90 100

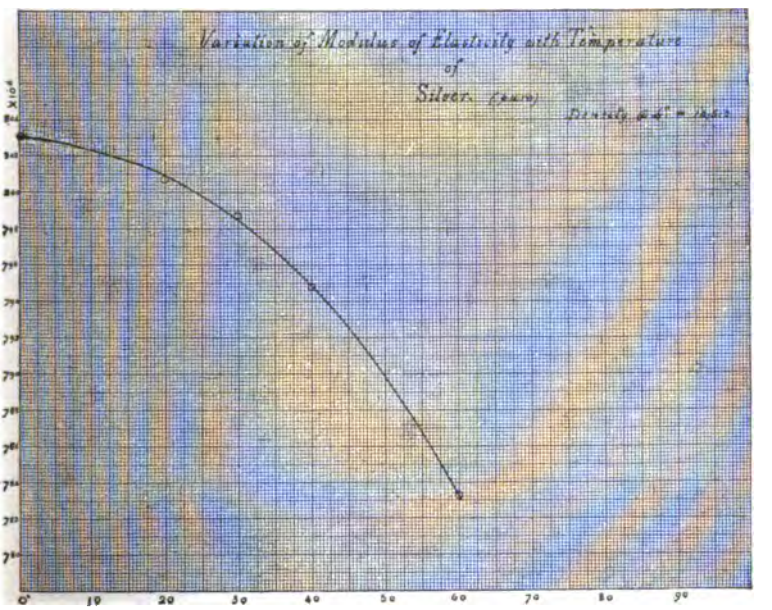
13.


Variation of Modulus of Elasticity with Temperature
Aluminium (American)
0° 10 20 30 40 50 60 70 80 90 100

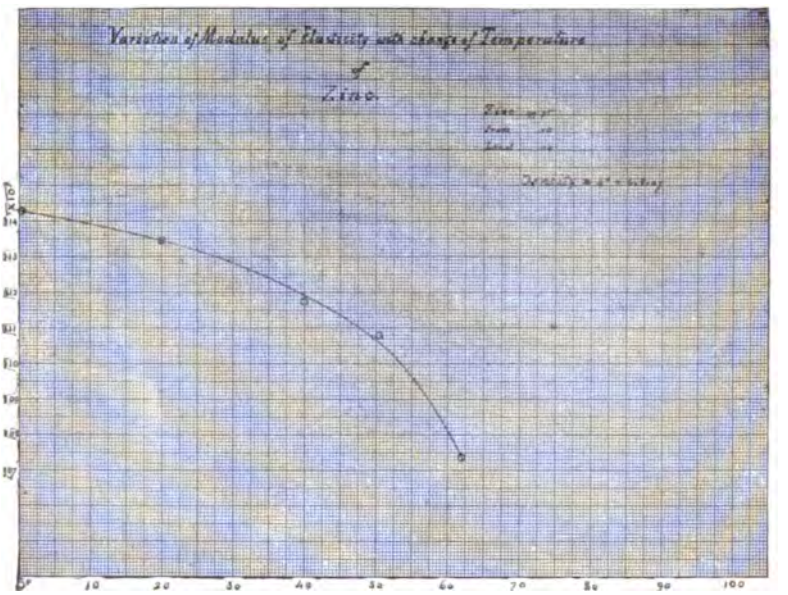
14.


Variation of Elasticity with Temperature.
Aluminium (Tensile).
Density at 0° = 2.710
0°
10
20
30
40
50
60
70
80
90
100

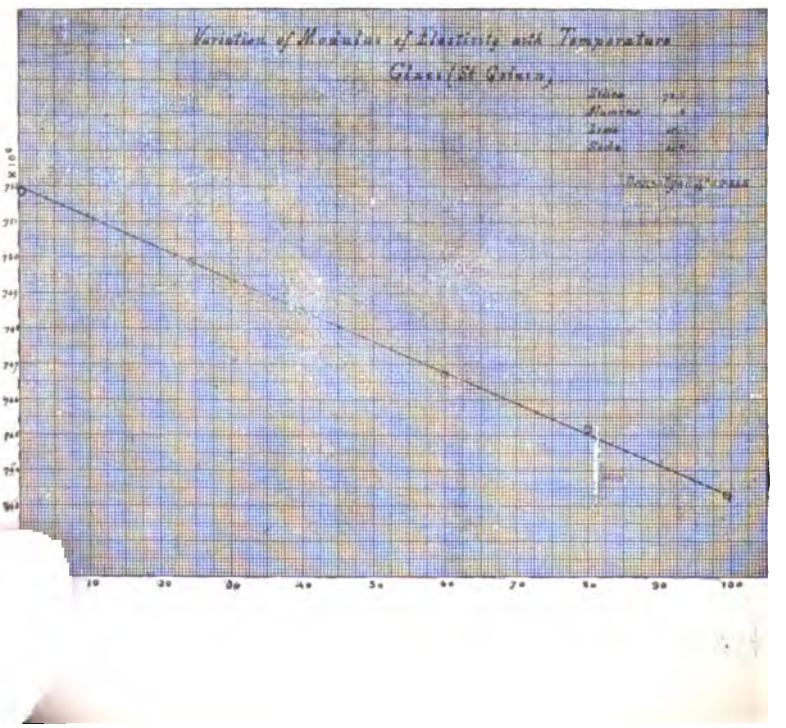
15.


Variation of Modulus of Elasticity with Temperature
of
Silver. (Tensile)
Density at 0° = 10.53
0°
10
20
30
40
50
60
70
80
90

16.


Variation of Modulus of Elasticity with change of Temperature
of
Zinc.

17


Variation of Modulus of Elasticity with Temperature
Glass (St Gobain)

RESULTS OBTAINED BY OTHER EXPERIMENTERS ON THE CHANGE OF THE MODULUS OF ELASTICITY WITH CHANGE OF TEMPERATURE.

I have found five researches on this subject. I here give abstracts of results from these papers.

Wertheim, 1844. Ann. de Chim. et de Phys.

IRON.

Modulus 5.2 per cent. greater at 100° than at 18°.
Modulus 19.1 per cent. less at 200° than at 100°.

IRON WIRE.

Modulus 4.9 per cent. greater at + 10° than at — 11°.6.
Modulus 7.42 per cent. greater at 100° than at 18°.

WIRE OF ENGLISH CAST STEEL.

Modulus 23.23 per cent. greater at 100° than at 18°.
Modulus 9.46 per cent. less at 200° than at 100°.
Modulus at 200° is 11.57 per cent. higher than modulus at 18°.

STEEL WIRE TEMPERED TO BLUE.

Modulus 1.97 per cent. higher at + 10° than at — 10°.
Modulus 5.1 per cent. higher at 100° than at 18°.

CAST STEEL.

Modulus 2.8 per cent. less at 100° than at 18°.
Modulus 5.73 per cent. less at 200° than at 100°.

SILVER.

Modulus 5 per cent. less at + 10° than at — 13°.8.
Modulus 1.87 per cent. greater at 100° than at 18°.
Modulus 12.87 per cent. less at 200° than at 100°.

COPPER.

Modulus 6.53 per cent. less at + 10° than at — 15°.
Modulus 6.58 per cent. less at 100° than at 18°.
Modulus 20. per cent. less at 200° than at 100°.

WIRE OF BERLIN BRASS (Cu. = 67.55 . Zn. = 32.35).

Modulus 7.95 per cent. less at + 11° than at — 10°.

Kupffer, 1856. Mem. de l'Acad. de St. Petersb.

Modulus of iron wire 5.5 per cent. less at 100° than at 0°.
Modulus of copper wire 8.2 per cent. less at 100° than at 0°.
Modulus of brass wire 3.9 per cent. less at 100° than at 0°.

Kohlrausch and Loomis, 1870. Pogg. Ann.

Modulus of iron wire 5 per cent. less at 100° than at 0°.
Modulus of copper 6 per cent. less at 100° than at 0°.
Brass 6.2 per cent. less at 100° than at 0°.

H. Tomlinson, 1887. Phil. Mag.

Says, "My own experiments show that both the torsional and longitudinal elasticities are decreased about 2½ per cent. when the temperature of steel is raised from 0° to 100°.

M. C. Noyes, 1895. The Physical Review.

Modulus of a piano wire $\frac{4}{10}^{mm}$ diam. 5 per cent. less at 100° than at 0°.

The results of Wertheim's experiments giving an increase to the modulus, as the temperature rises, of iron, iron wire, wire of English cast steel, steel wire drawn to blue and silver, have not been confirmed in any instance by subsequent experiments; only for cast-steel *rod* and copper did he obtain a diminution of modulus for a rise of temperature from 18° to 100°. Yet, he found that a *wire* of English cast steel had a modulus 23 per cent. higher at 100° than at 18°.

ON THE ACOUSTICAL PROPERTIES OF ALUMINUM.

The low density (2.7) of aluminum combined with a modulus of elasticity of only 712×10^6 render this metal easy to set in vibration; a transverse blow given to a bar of this metal causes it to vibrate with an amplitude of vibration greater than that which the

same energy of blow gives to a similar bar of steel or of brass. This fact has given rise to the popular opinion that aluminum has sonorous properties greatly exceeding those of any other metal. This opinion is erroneous. If a bar of aluminum and a bar of brass having the same length and breadth and giving the same note are struck transversely so that the bars have the same amplitude of vibration, the bars give equal initial intensity of sounds; but the bar of aluminum from its low density and because of its internal friction will vibrate less than one-third as long as the bar of brass. Thus, a bar of aluminum and a bar of brass of the same length and width and of such thickness that they gave the same note, SOL_4 of 768 v. d., were vibrated so that the sounds at the moment of the blows were, as near as could be judged, of the same intensity. The duration of the sound of the brass bar lasted 100 seconds; the sound of the aluminum bar lasted 30 seconds.

The readiness with which a bar of aluminum vibrates when acted on by aerial vibrations of the same frequency as those given by the bar, gives one the means of making many charming experiments in which "sympathetic vibrations" come into play.

I here describe an experiment devised by me to show the interference of sound in a manner similar to analogous experiments in the case of light. The resonant box on which Kœnig mounts his UT_5 (1024 v. d.) fork is open at both ends and has a length of nearly a half-wave of the sound of the fork. If this resonant box is held with its axis vertical, above an aluminum bar in tune with the vibrating fork, the bar does not enter into sympathetic vibration with the fork, because the sonorous pulses, on reaching the aluminum bar from the two openings of the resonant box, differ in phase by one-half wave-length. But if the axis of the box is held parallel to the axis of the bar, then the sonorous waves reaching the bar have traveled over equal lengths from the openings at the ends of the box, and these waves conspire in their action and the aluminum bar enters into sympathetic vibration.

As this experiment is an interesting one, I here give details as to the manner of making it. The bar of aluminum has a large surface, having a length of 17^{cms} and a width of 5^{cms}. The two nodal lines, which are distant from the ends of the bar equal to two-ninths of its length, are drawn on the bar. The bar is supported under these nodal lines on threads stretched on a frame. This frame is of such a height that the under surface of the aluminum bar is 8.4^{cms}, or one-quarter wave length, above the surface of the table, so that the vibrations of the bar and those of the waves reflected from the table will act together. The upper surface of the bar is covered with a piece of thick cardboard, in which is cut a rectangular aperture, having for length the distance between the nodal lines and a width equal to that of the bar. As this piece of cardboard rests on supports which lift it a slight distance above the surface of the bar, the latter, when it vibrates, does not send to the ear the vibrations of the surfaces of the bar included between its nodal lines and its ends, and which vibrations are opposed in phase to those given by the central area of the bar. Thus the sound emitted by the bar is much increased and the experiment rendered more delicate and improved in every way. I have found that the experiment succeeds best when the center of the resonant box is held about 58^{cms}, or, $7\frac{\lambda}{4}$ above the surface of the aluminum bar. This experiment works best in the open air, away from the action of sound-waves reflected from the walls and ceiling of a room.

The fact that aluminum gives, from a comparatively slight blow, a great initial vibration and that its vibrations last for a short time, render this metal peculiarly well suited for the construction of those musical instruments formed of bars which are sounded by percussion and the duration of whose sounds is not desirable.

I had hopes that aluminum would prove to be a good substance out of which to make plates on which to form the acoustic figures of Chladni. Experiments have shown that aluminum is

not suited to this purpose. I had plates of aluminum carefully cast, with 2^{cms} of thickness. These plates were turned down on the face-plate of a lathe to thicknesses of 2^{mm} and 3.8^{mm}. Three of these plates were quite homogeneous in elasticity, for the Chladni figures when obtained on them were symmetrical. Yet the Chladni figures were difficult to produce, because it is difficult to obtain a pure tone from an aluminum plate. The sound is generally more or less composite; therefore the plate in its vibration tends to form two or more figures at the same time, and the consequence is that either no figure is formed or one is given that is not sharply defined. One square plate of 30.8^{cms} on the side and 0.38^{cm} thick, gave quite clearly the three following tones: UT_2 (1), SOL_2 (2), and SOL_4 (3). Corresponding respectively to the Chladni figures of (1) two lines drawn between opposite points of the center of sides of plate; (2) figure formed of the two diagonals drawn between the corners of plate; (3) figure similar to (1) but with corners of plate cut off by curved lines. Figure 3 corresponded so nearly to the sound of SOL_4 that a vibrating SOL_4 fork when held near the plate set the latter into vigorous vibration.

Another difficulty met with in using plates of aluminum for Chladni's figures is that sand, even when entirely free of salt and of the globular grains of wind-blown sand, does not move freely over a vibrating surface of aluminum, whether this surface has been polished or has been slightly tarnished and roughened by the action of alkali.

There is one serious objection to the use of aluminum in the construction of musical and acoustical instruments, and that is the great effect that a change of temperature has upon its elasticity. If a bar of aluminum and a bar of cast steel be tuned at a certain temperature to exact unison, a change from that temperature will affect the frequency of vibration of the aluminum bar $2\frac{1}{2}$ times as much as the same change of temperature will affect the bar of cast steel.

EXPERIMENTAL DETERMINATION OF THE INFLUENCE OF BACK PRESSURE ON THE ECONOMY OF A SURFACE CONDENSING ENGINE WITH INDEPENDENT VACUUM PUMP.*

BY PERCY ALLAN, '95; G. EVERETT BRUEN, '95; FRED'K K. VREELAND, '95.

It is not always economical to run a condensing engine at the highest possible vacuum. This fact is due, in the main, to two causes: First, an increase of vacuum, although it increases the mean effective pressure of the engine, at the same time entails a corresponding decrease in the temperature of the feed water, and therefore a greater expenditure of heat at the boiler per pound of water evaporated; and second, more power is required to run the vacuum pump with a high than with a low vacuum.

Besides these two principal factors, there are several others which enter into the case.

1. An increase in the vacuum does not produce an equal decrease in the back pressure; for the steam, having less density, meets with greater resistance in passing through the ports, and so the drop in pressure between the cylinder and condenser is increased.

2. The temperature of the condensed steam is always lower than the boiling point of water at the pressure existing in the condenser, and this difference of temperature is not a constant one, but varies with the absolute pressure in the condenser.

3. The power absorbed by the air pump is not directly proportional to the vacuum.

4. The diminished back pressure entails a lower temperature in the cylinder at exhaust, and so may alter the cylinder condensation. It was at first intended to determine this factor by experiment, but as it was, at most, a very insignificant quantity for the variation of back pressure existing in the tests, it was omitted for reasons which will appear later.

The laws which govern the above factors are too complicated to be calculated directly, and it has been the object of this research to secure data which may assist in solving the problem.

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* Graduating Thesis.

DESCRIPTION OF APPARATUS.

A general plan of the apparatus used is shown in Fig. 1. The engine was a Buckeye, 7x14 inches, having an automatic flywheel governor attached to a riding cut off valve, and is in constant use in the machine shop of the Stevens Institute of Technology. The engine was run under the same conditions as exist in the low-pressure cylinder of a compound engine, which made it necessary to supply it with steam at a comparatively low pressure. The pressure of steam furnished by the boilers was about 75 pounds per square inch above the atmosphere, and it was throttled to the desired pressure, before reaching the engine. The steam was supplied by a 2½-inch pipe (newly covered with magnesia sectional covering) direct from the boiler, reducing to 2 inches at A. The pressure of steam entering the steam chest was regulated to 15 pounds above the atmosphere by adjusting the valve B. The main throttle at the engine was wide open during the tests. A steam gauge gave the pressure of the steam after it was throttled by the valve B. Towards the end of the tests, a drip was placed in the steam pipe C, in order to get rid of any entrained water, and a mercury well was introduced between B and the engine in order to determine the amount of superheating in the low-pressure steam.

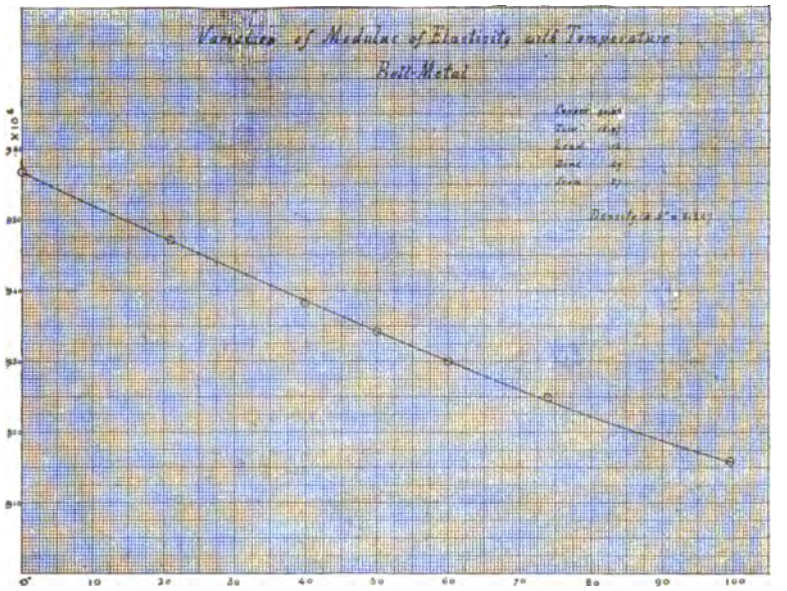
Steam for the pump and auxiliary engine was taken from the main before reaching B, so as to obtain full boiler pressure.

The exhaust from the engine was conducted by a 2½-inch pipe through the machine shop floor to a Wheeler surface condenser placed in the basement. The connection ordinarily used for exhausting into the atmosphere outside the building was closed by a gate valve, and means were provided for sealing the same with water to make certain that there was no leakage of air into the condenser.

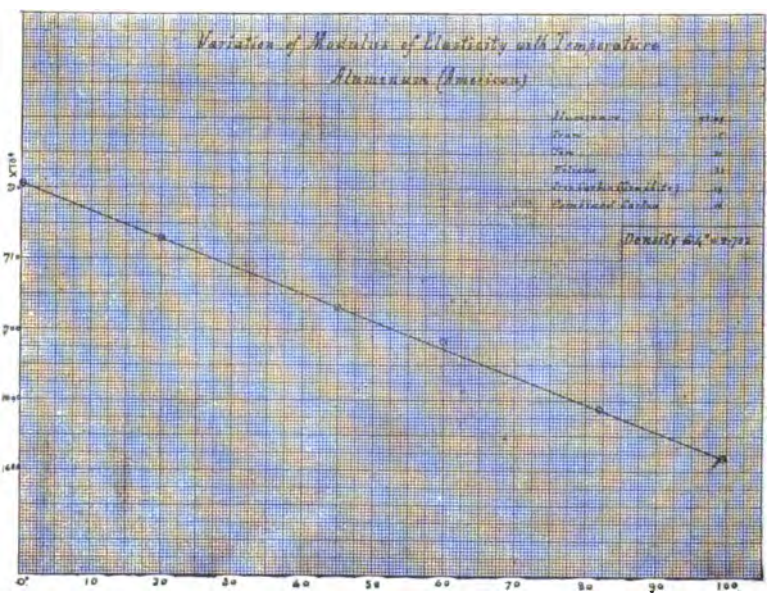
The discharge from the condenser passed through a 2-inch pipe to a Blake air pump 6″x8″x12″, placed in the basement, and from thence by a 1¼-inch pipe to weighing barrels. A mercury well, placed in the discharge pipe as near as possible to the condenser, gave the temperature of the condensed steam. The Blake pump was kindly loaned us by the manufacturers.

Condensing water was supplied direct from the city mains by a 2-inch pipe controlled by a gate valve D, passing first through a pipe containing a mercury well, and through a meter. Another

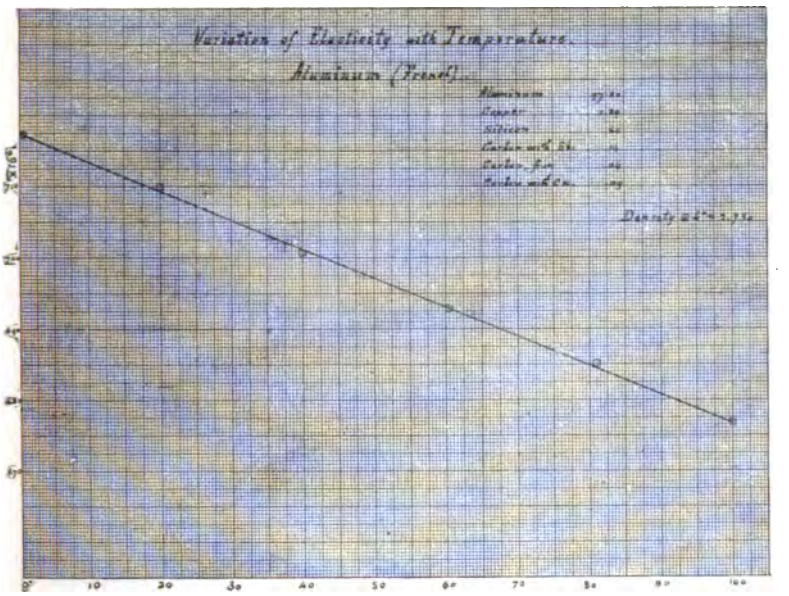
12.


Variation of Modulus of Elasticity with Temperature
Bell-Metal
0° 10 20 30 40 50 60 70 80 90 100

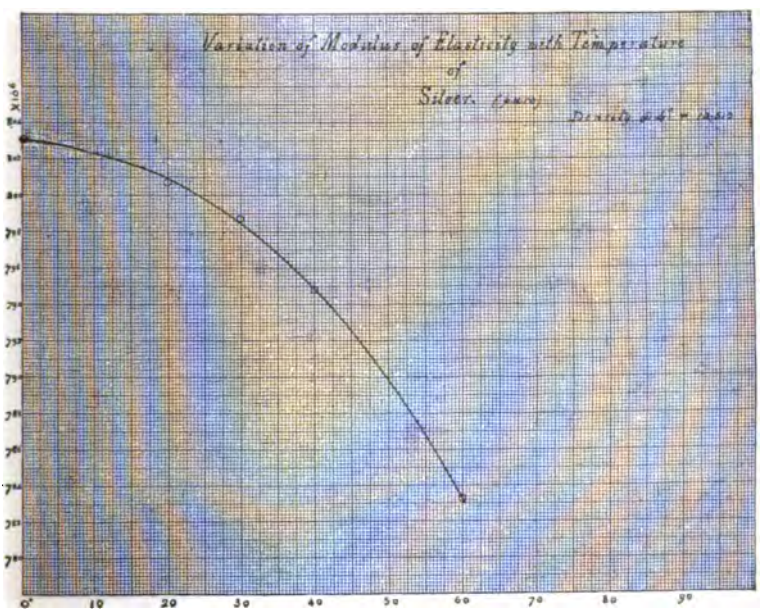
13.


Variation of Modulus of Elasticity with Temperature
Aluminium (American)
0° 10 20 30 40 50 60 70 80 90 100

14.


Variation of Elasticity with Temperature.
Aluminium (French).
Density at 0° = 2.710
0° 10 20 30 40 50 60 70 80 90 100

15.


Variation of Modulus of Elasticity with Temperature
of
Silver. (Tensile)
0° 10 20 30 40 50 60 70 80 90

Dimensions of pump:

Diameter of steam cylinder, 6 inches.
Diameter of air cylinder, 8 inches.
Stroke during tests, 11.75 inches.
Diameter of piston-rod, 1⅛ inches.

FINAL RESULTS OF TESTS AND COMPUTATIONS.

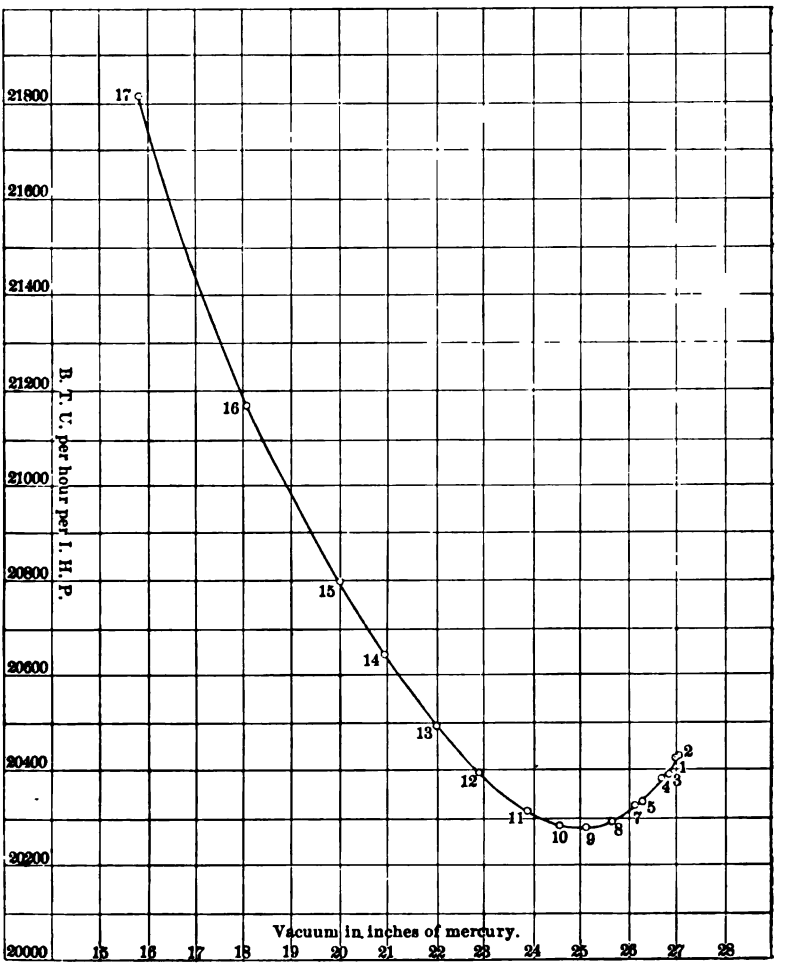
It was found that the economy of the engine on the heat-unit basis, which allows for differences in the temperature of the feed, so as to represent the economy starting from the coal pile, was a maximum for a vacuum of 25 inches of mercury. The final results of the tests are shown in Fig. II. The economy diminished, on increasing the vacuum, from 25 to 27 inches, so that the economy at 27 inches was about the same as the economy with a vacuum of about 22½ inches.

It was also demonstrated that there will be, in general, a certain vacuum that will give the best economy for a given case, and that the most economical vacuum will vary for different engines.

To do this two compound engines, which are types of the best modern practice, were considered. First, a Harris-Corliss engine of 1,600 horse-power, at the works of the Bristol Manufacturing Company, New Bedford, Mass., running at 65 revolutions per minute; and second, the Pawtucket pumping engine, of 145 horse-power, and running at 45 revolutions per minute. The steam pressure in both cases was about 120 pounds above the atmosphere. The vacuum best suited for the Harris-Corliss engine, assuming that an independent circulating and vacuum pump was used, was demonstrated to be 25 inches. The curve A A A given in Fig. III. shows the economy at different vacuums. The vacuum best suited for the Pawtucket engine, assuming that an independent circulating and vacuum pump was used, was 26½ inches. The curve A A A in Fig. IV. shows the economy with different vacuums.

One element that causes the best economy of the Pawtucket engine to correspond to a higher vacuum than in the case of the Bristol engine, is that the low speed and ample port area of the Pawtucket engine cause the vacuum realized in the low-pressure cylinder to be very nearly the vacuum in the condenser; whereas, in the case of the Bristol engine, which runs at a higher speed, there was a loss of pressure, when run under the conditions existing at

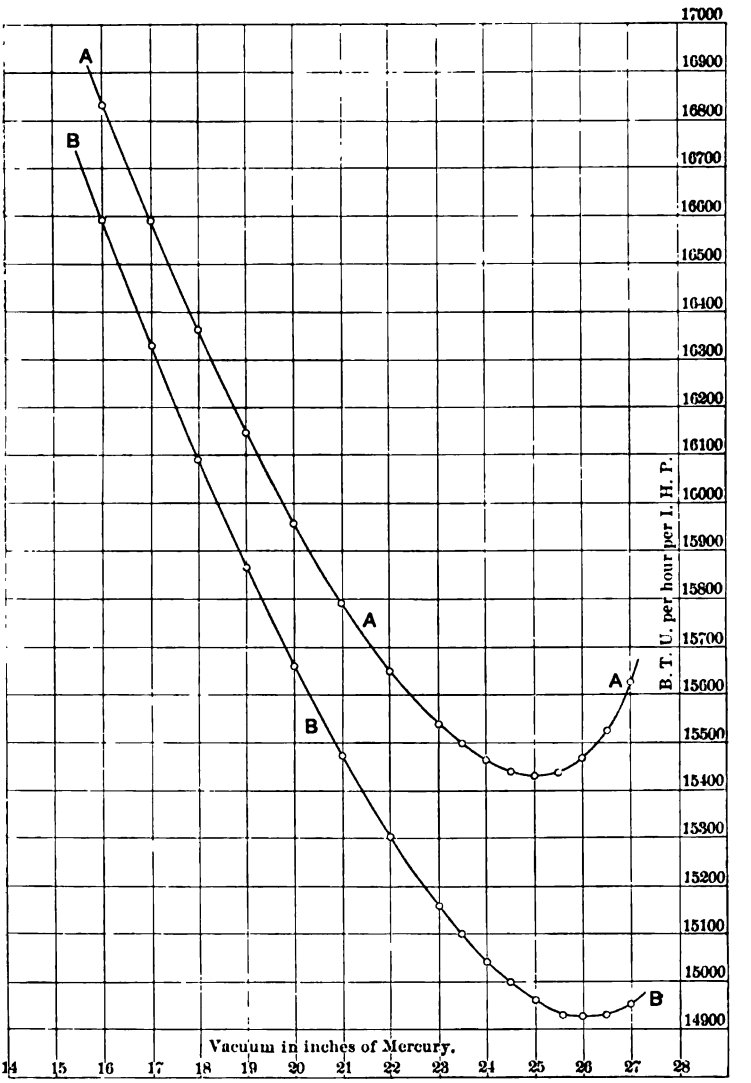
FIG. II.



ECONOMY CURVE FOR SMALL COMPOUND ENGINE WITH AN INDEPENDENT VACUUM PUMP.—Engine assumed to have a low-pressure cylinder of same size as the cylinder of the Buckeye Engine.

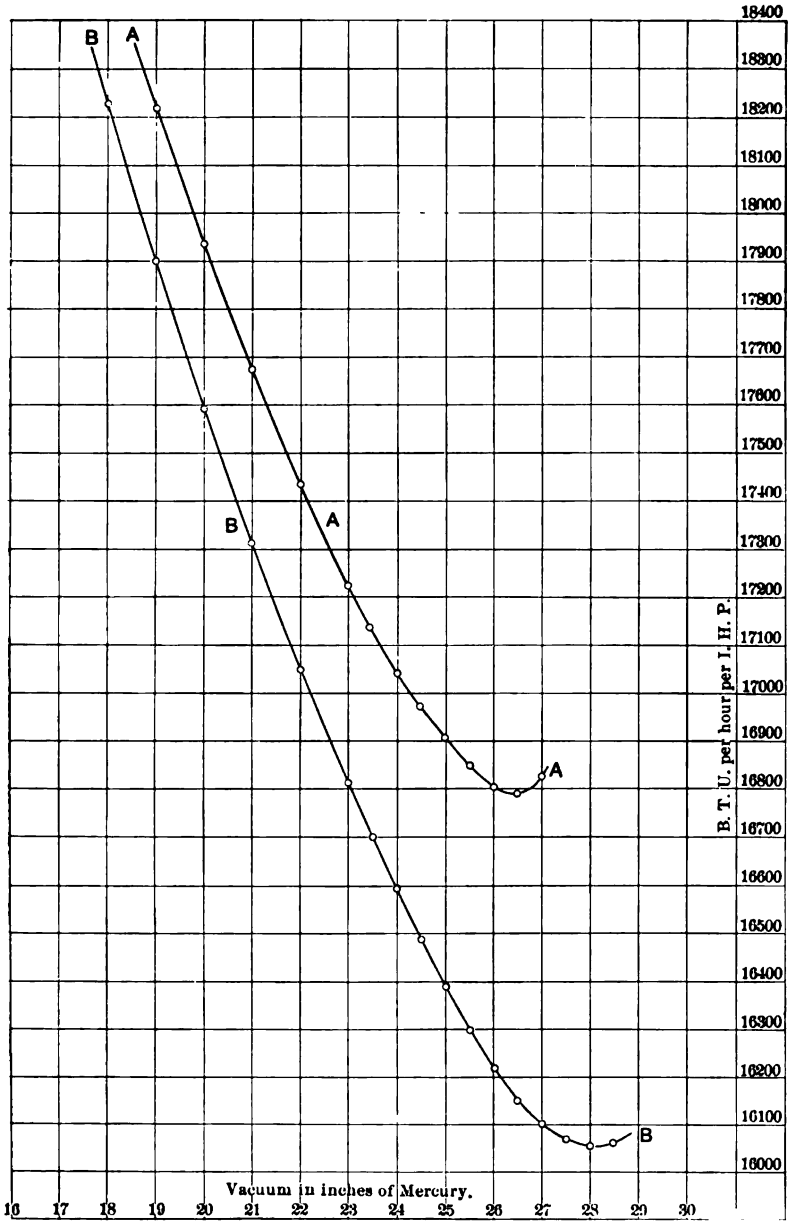
British thermal units imparted to boiler per hour per indicated horse-power of engine.

FIG. III.



ECONOMY CURVES FOR HARRIS-CORLISS ENGINE.—The curve A A A represents the economy per indicated horse-power of engine, if an independent circulating and vacuum pump is employed. The curve B B B represents the economy per total indicated horse-power, including power required to run the vacuum and circulating pump, when the latter is driven directly from the crosshead of the main engine.

FIG. IV.



ECONOMY CURVES FOR PAWTUCKET ENGINE.—The curve A A A represents the economy per indicated horse-power of engine, if an independent circulating and vacuum pump is employed. The curve B B B represents the economy per total indicated horse-power, including power required to run the vacuum and circulating pump, when the latter is driven directly from the crosshead of the main engine.

the time of the test, of about 1.4 pounds per square inch in the exhaust steam on passing through the low-pressure cylinder ports.

The results for the above two cases were computed from data obtained from published tests,* and the method of computation will be presented later on.

The economy for vacuum pumps driven directly by the engine was also considered. In this case the indicated horse-power includes the power required to drive the pump, so that the vacuum obtained is that for which the economy per total indicated horse-power will be the greatest. The vacuum best suited for the Harris-Corliss engine under the latter assumption was found to be 26½ inches, and for the Pawtucket 28 inches.

The curves B B B in Figs. III. and IV. show the economy with different vacuums with pumps driven from the main engines.

METHOD OF CONDUCTING TESTS.

As it was desired to run the engine under the same conditions as exist in the low-pressure cylinder of a compound engine, the governor was blocked so as to entirely prevent its action, to insure a uniform point of cut-off, which was made to occur at about one-half stroke. The pressure of steam at the engine was 15 pounds per square inch above the atmosphere.

A small upright engine, with an ordinary throttling governor, was belted to the shafting and used to regulate the speed, as well as to supply the necessary power. At times, the power of the Buckeye engine alone was in excess of that required to run the shop. To absorb this excess of power, a Baker pressure blower was belted to the main shafting, and by throttling its discharge pipe the load could be adjusted and a close regulation of speed effected. The revolutions were maintained as near as possible to 193 per minute.

The vacuum in the condenser was regulated by throttling the condensing water at D, Fig. 1, and was maintained very nearly constant throughout each test. The speed of the pump was adjusted to about 10 revolutions per minute by means of a throttle valve in the steam supply pipe.

* Results of Measurements of the Water Consumption of an Unjacketed 1,600 Horse-Power Compound Harris-Corliss Engine. *Transactions*, A. S. M. E., Vol. XV., p. 882.

On the Influence of the Steam Jackets on the Pawtucket Pumping Engine. *Transactions*, A. S. M. E., Vol. XI., p. 328; also same volume, p. 1038, and Vol. XII., p. 194.

Readings were taken every 10 minutes, the duration of the tests being usually about 1½ hours. Table I. shows the data taken in full for one test.

METHOD OF CALCULATING RESULTS.

I.—GENERAL DATA.

The data of each test were tabulated as shown in Table I., which gives in full the data of test No. 3. The columns were averaged as shown, and corrected for instrumental errors as described later on, and the corrected figures entered in Table II.

II.—ENGINE CARDS.

The areas of the engine cards were determined by a planimeter, by two independent observers, whose results were averaged as shown in Table III. The M. E. P. was found for the two ends of the cylinder separately, using the corrected scale of spring, and the horse-power entered in Table IV., column 5. The vacuum realized on each card (Table III., columns 2–4), was measured from the atmospheric line to the lowest point of the back-pressure line, at three-quarters stroke, the average corrected for the scale of spring, and entered in Table IV., column 2. From this column

FIG. V.

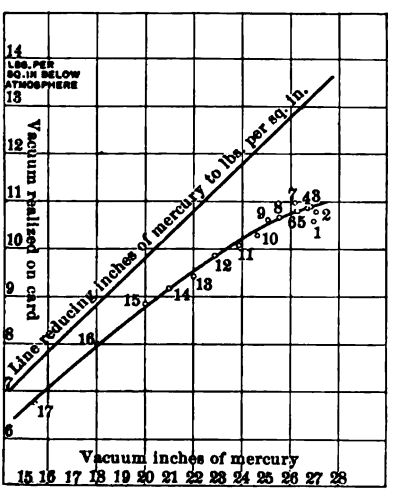
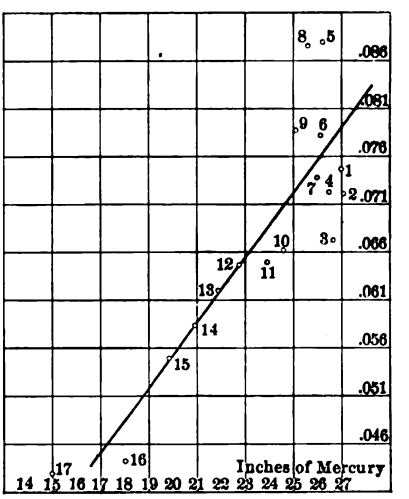


FIG. VI.



The lower line of Fig. V. represents vacuum realized in cylinder of Buckeye Engine for various vacuums in condenser, and the upper line the corresponding vacuum in condenser.

Fig. VI. represents the horse-power absorbed by vacuum pump for various vacuums in tests of Buckeye Engine.

we get the curve in Fig. V., the co-ordinates of which are, respectively, the vacuum as measured by the mercury column, and the vacuum in pounds per square inch realized on the card. The straight line on the plate gives the equivalent in pounds per square inch of the vacuum in the condenser, and the vertical distance between those two lines is the drop in pressure between the cylinder and the condenser.

III.—PUMP CARDS.

The areas of the pump cards were also determined by a planimeter, and averaged as in Table V. The stroke of the pump was so nearly constant that the length of the card varied not more than 0.03 inch, and, as any variation in stroke was accompanied by a proportionate variation in the length of card, the two effects balanced each other in such a way as to make the work directly proportional to the area of the indicator cards.

The horse-power was found in the same way as that of the engine, and entered in Table V., column 4, and average results are shown in Fig. VI.

IV.—CORRECTION OF HORSE-POWER OF PUMP.

It will be seen from Table II., column 16, that it was impossible to keep the speed of pump constant during all the tests; and, as the pump was run far below its rated capacity, the horse-power consumed in friction was a considerable quantity, compared to the total power. It was inconvenient to indicate the air cylinder, so the net horse-power was found as follows: Friction cards were taken from the pump, and it was found that the areas of the cards were practically independent of the speed. It is therefore fair to assume that the horse-power absorbed in friction was directly proportional to the speed, and is equal to $\frac{p.\ l.\ a.\ n.}{33000}$ for each end, or total $= .00505\ N$. Column 5, Table V., is calculated from this formula, and this subtracted from column 4 gives the net horse-power, column 6.

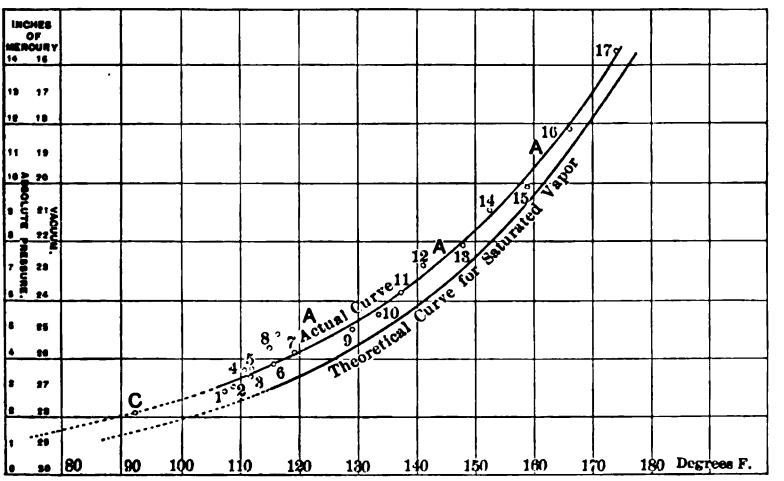
As the quantity of water pumped was variable, this also affected the horse-power of the pump, and the correction was made as follows: The volume in cubic feet of any excess of water over the standard of 420 pounds per hour (see page 149)

was multiplied by the pressure against which it was pumped —i. e., the equivalent in pounds per square foot of the vacuum— and this product, divided by 33000×60, gave the horse-power absorbed in pumping this excess, Table V., column 8. This column subtracted from column 6 gives column 9, which, being plotted, gives Fig. VI., in which the abscissas are the vacuums and the ordinates the horse-power.

V.—TEMPERATURE CURVE OF CONDENSED STEAM.

The temperature of the condensed steam is a function of the absolute pressure in the condenser. To find the law by which it varies, the difference between the barometer reading, Table II., column 5, and the vacuum by mercury column, column 3, gave the absolute pressure, while the temperature was found by the thermometer in the discharge pipe, column 4; and these figures taken as co-ordinates give the curve, Fig. VII. To apply this curve to a series of tests, it is necessary to assume a constant atmospheric pressure,

FIG VII.



TEMPERATURE CORRESPONDING TO VARIOUS PRESSURES IN CONDENSER AND OF CONDENSED STEAM ON LEAVING CONDENSER.—The curve A A A gives the temperature of the condensed steam on leaving condenser of the Buckeye Engine. The point C gives the temperature of water leaving the jet condenser of the Pawtucket Engine, and the dotted curve which is made to pass through it has been used in the computations for the same.

which was taken at 30 inches of mercury at 70° Fahr The lower curve on this plate is the curve of temperature of saturated vapor at different pressures as plotted from a steam table.

Having the three curves, Figs. V., VI., and VII., we can compute the most economical vacuum under the given conditions.

We will first find how the vacuum affects the horse-power of the engine.

VI.—EFFECT OF VACUUM ON HORSE-POWER OF ENGINE.

As the steam pressure, cut-off, and speed of engine are constant, the upper part of the card must be always the same, while the back-pressure line changes with the vacuum. It is a very close approximation to the truth to assume that the back-pressure line has always the same form, and simply rises or falls with the changes of vacuum ; so that every pound of vacuum realized on the card, measured as described in Article II. of this section, adds a pound to the mean effective pressure. It is on this basis that the calculations rest. From the average M. E. P., Table VI., column 2, is subtracted the average vacuum realized, Table IV., column 2, and the difference is the equivalent M. E. P. for zero vacuum. To this figure we add the vacuum realized, Table VI., column 3, as found from the curve, Fig. V., and we obtain the corrected M. E. P., Table VI., column 4.

We must now find the

VII.—ENERGY EXPENDED PER HORSE-POWER.

This is in three parts :

(1) The total heat of the steam fed to engine per hour.

(2) The total heat of the steam used by the air pump.

(3) The heat returned to the boiler through the feed water.

(1) During the earlier tests of the series, the amount of steam used by the engine was so variable as to point to the conclusion that the steam, notwithstanding that it was throttled from about 75 pounds pressure to 15 pounds, still contained moisture. To settle this point, a drip pipe was put in the main steam pipe at C, Fig. I., and steam allowed to blow out of it freely during the subsequent tests. A mercury well inserted in the steam pipe between the throttling valve and the engine indicated no superheating when the drip valve at C was closed, and from 5° to 15° Fahr. of

superheat when the drip valve was opened. The action of the drip valve reduced the steam consumption to an average of 420 pounds per hour in tests 15 to 17 inclusive, and this figure was taken as the correct one. The total heat above 32° Fahr. of steam at 120 pounds gauge, or 135 pounds absolute pressure, is 1,188 B. T. U. per pound. This gives for the total heat in the steam supplied to the engine $= 420 \times 1188 = 498,960$ B. T. U. per hour $= (a)$.

(2) As has been noted before, the vacuum pump was run far below its rated capacity, and therefore showed an abnormal steam consumption. To reduce it to actual running conditions, let us assume that the vacuum is maintained by a compound pump using 40 pounds of steam per horse-power per hour. This, at 120 pounds pressure, would be $40 \times 1188 = 47,520$ B. T. U. per hour per horse-power. This figure, multiplied by the horse-power from the curve, Fig. VI., gives the B. T. U. per hour absorbed by the pump, column 3, Table VII. $= (b)$.

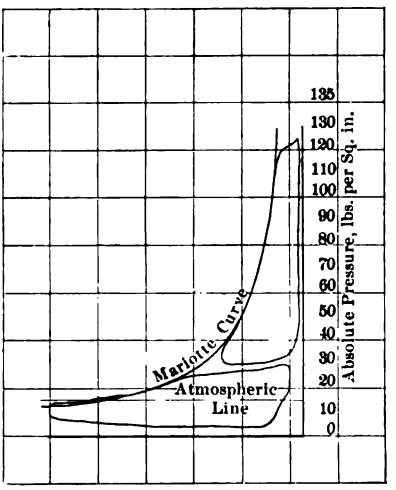
(3) The heat returned in the feed water is found by taking the temperature from the curve, Fig. VII., minus 32° Fahr. and multiplying by the standard weight of 420 pounds per hour, which gives the B. T. U. returned to boiler, column 4, Table VII. $= (c)$.

We now find $(a + b - c)$ which is the total number of B. T. U. expended per hour, column 5. We may consider the heat units in column 5 to belong to any style of engine whose back pressures for various vacuums correspond with Fig. V. Suppose, for example, that such was the case with a compound engine expanding steam about 12 times from a boiler pressure of 120 pounds, affording cards as represented in Fig. VIII. It is known by experiments on engines generally that the water consumption of such an engine may be assumed at 18 pounds per hour per indicated horse-power, at the greatest vacuum covered by the experiments, not including the consumption of the air pump.

For 420 pounds of steam consumption per hour by the engine alone, therefore, the indicated horse-power would be $\frac{420}{18} = 23.3$ horse-power, or say, for convenience in calculating, 23.1035 horse-power, which would correspond to the mean effective pressure in the low-pressure cylinder of 16.78 pounds per square inch, given in line 1, column 4, Table VI., plus the M. E. P. of the high-pressure cylinder reduced to its equivalent on the low-

pressure piston. This, assuming that the horse-power is about equally divided between the high and low cylinders as represented in Fig. VIII., will be about 16 pounds, and is so taken. For the various vacuums the corresponding mean effective pressures would be given by the values in column 3, Table VI., plus 16 pounds, and the corresponding horse-powers as per column 5, Table VI. Dividing the heat units expended per hour, column 5, Table VII., by the respective horse-powers given in column 5, Table VI., we

FIG. VIII



COMBINED DIAGRAMS OF INDICATOR CARDS.—Low-pressure card is that obtained from Buckeye Engine and high-pressure diagram constructed so as to divide the power equally between the two cylinders.

obtain the B. T. U. per hour per horse-power for such an engine at various vacuums, using a surface condenser of the proportions we employed in our tests, with the minimum supply of condensing water necessary to secure the several vacuums, and with an independent compound air pump, using 40 pounds of steam per hour per indicated horse-power of such pump.

Plotting these values of the B. T. U. per hour per horse-power, as given in column 6, Table VII., affords the curve given in Fig. II. This curve shows a minimum number of B. T. U. per

horse-power of the system at 25 inches of vacuum, which is therefore the most economical vacuum.

SPECIAL TESTS OF VACUUM PUMP USED IN TESTS OF THE BUCKEYE ENGINE.

In order to find the effect on the horse-power and economy of the pump, of pumping various amounts of water, a series of tests was made at vacuums of 26 and 21 inches. Part of the water was supplied by the exhaust from the engine, and the remainder was sucked up from a barrel through a pipe connected with the condenser for the purpose. It was found that with a large amount of water the vacuum had little effect on the horse-power, which was nearly proportional to the amount of water pumped. On the other hand, the previous tests indicated that when the amount of water was small, the vacuum was the principal factor in the case. It was also found that the economy of the pump improved as the amount of water pumped became greater.

CALIBRATION OF INSTRUMENTS.

The indicator springs used were carefully calibrated with steam pressure. In doing this, the pressure was read by means of a mercury column reading up to 30 pounds. The 20 spring used on the engine was calibrated at pressures below the atmosphere, the vacuum being measured by a mercury column. For the 30 spring no correction was deemed necessary. The table shows that it was sensibly correct, except at atmospheric pressure. As the spring was used only to determine horse-power and not absolute pressure, the correction disappears. The 20 spring was corrected to 20.3.

All the gauges were calibrated by means of an apparatus, in which the pressures are obtained by loading with known weights an accurately ground plug of known area fitting into a collar and resting on oil.

The thermometers used for measuring the temperature of water were subjected to the usual laboratory tests at 32° and 212° Fahr, and no appreciable errors were found. The one used for measuring the temperature of steam was tested by means of saturated steam, the pressure of which was measured by a calibrated gauge

The planimeter used was carefully tested, before working out each lot of cards, by running it several times around a circle of known diameter by means of a radius arm pivoted at the center. The error found was so small that it was within the limits of observation.

GENERAL METHOD OF FINDING THE MOST ECONOMICAL VACUUM APPLIED TO TWO OTHER ENGINES.

We shall apply this method to two engines which are types of the best modern practice.

1. The Harris-Corliss engine at the works of the Bristol Manufacturing Company, New Bedford, Mass.*

2. The Pawtucket pumping engine.†

We will assume that the engines exhaust into a surface condenser, and that a combined circulating and vacuum pump is employed, having compound steam cylinders. The power to drive the circulating pump, as well as the efficiency of the condenser, will vary for different cases. In the present case the power required to circulate the water was assumed to be the same as that found for a Blake combined circulating and vacuum pump used on a 780 horse-power ferryboat engine.

In addition to computing the vacuum corresponding to the best economy with an independent vacuum and circulating pump, the vacuum that will give the best economy if the pump be driven directly from the main engines, is computed. In this case the horse-power of the engines includes the power to drive the pump, so that the vacuum thus obtained corresponds to the vacuum at which there would be a maximum economy per total indicated horse-power.

The engines were actually fitted with jet condensers, and the vacuum pumps were driven from the engine crossheads; hence, the most economical vacuums corresponding to the last set of conditions will approach more nearly to the most economical vacuums for the actual running conditions.

In the calculations it is assumed that the water was fed to the boiler directly on leaving the condenser, whereas, cold feed water,

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* *Transactions*, Am. Soc. M. E., Vol. XV., p. 882.

† *Transactions*, Am. Soc., M. E., Vol. XIII., p. 194

direct from the supply mains, was passed through a heater between the low-pressure cylinder and the condenser of the Bristol engine, and the condensed steam from the jackets of the Pawtucket engine, when run under the economical conditions, mingled with the water leaving the condenser; so that the feed water was at a higher temperature than the water leaving the hot-well.

To eliminate the action of the condensation from the jackets in heating the feed water in the case of the Pawtucket engine, a test was selected in which the jackets were not in use. The calculations, therefore, give the British thermal units per hour per horse-power for conditions which do not produce the maximum attainable economy in the engine.

The curve of vacuum realized in the cylinder, Fig. V., which is reproduced in Fig. IX., probably varies with every individual engine, and unless indicator cards at several vacuums are available we cannot construct such a curve. If we assume, however, as a fair

FIG. IX.

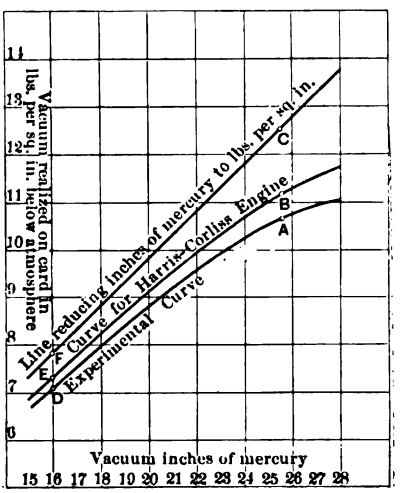
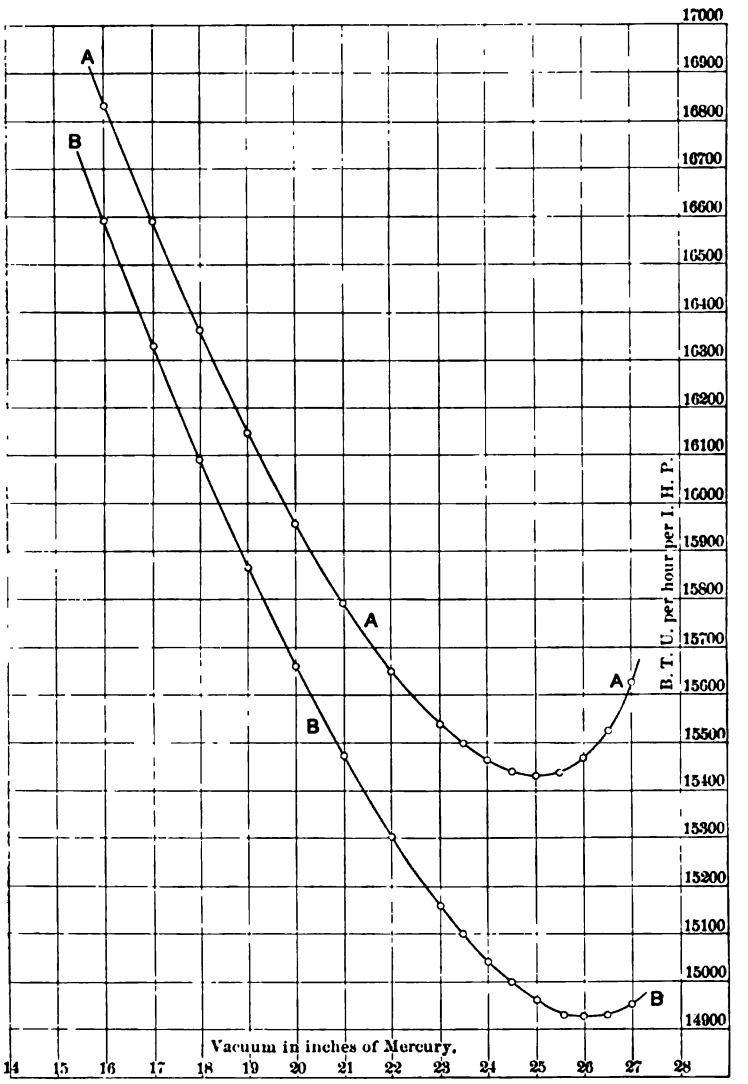


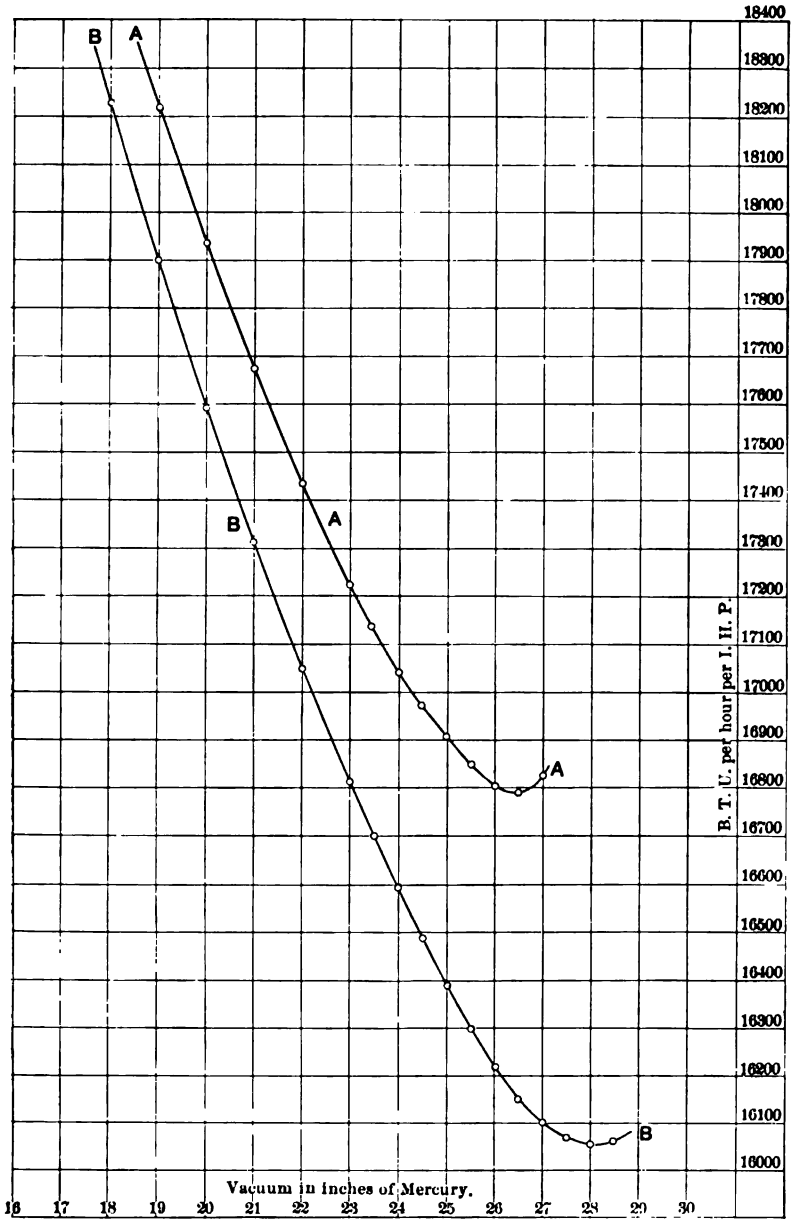
FIGURE IX. REPRESENTS VACUUM REALIZED IN CYLINDERS FOR VARIOUS VACUUMS IN CONDENSER.—The curve D A is that obtained by experiment for the Buckeye Engine. One point of the curve E B for the Harris-Corliss Engine is determined by experiment and remainder of curve constructed by method given on page 154.

FIG. III.



ECONOMY CURVES FOR HARRIS-CORLISS ENGINE.—The curve A A A represents the economy per indicated horse-power of engine, if an independent circulating and vacuum pump is employed. The curve B B B represents the economy per total indicated horse-power, including power required to run the vacuum and circulating pump, when the latter is driven directly from the crosshead of the main engine.

FIG. IV.



ECONOMY CURVES FOR PAWTUCKET ENGINE.—The curve A A A represents the economy per indicated horse-power of engine, if an independent circulating and vacuum pump is employed. The curve B B B represents the economy per total indicated horse-power, including power required to run the vacuum and circulating pump, when the latter driven directly from the crosshead of the main engine.

Water pumped by circulating pump.... 455,000 lbs. per hour.
Horse-power per pound of water circulated per hour..... $\frac{9.36}{455000} = .00002057$ horse-power.

Ratio of condensing water to condensed steam ..... $\frac{455000}{14000} = 32.5$

The ratio of condensing water to condensed steam just found agrees so closely with the figures obtained from Fig. X. at the same vacuum (33.25 at 26 inches vacuum) that the values from Fig. X. are taken without correction.

The horse-power absorbed in circulating the water at any vacuum is found as follows:

Determine the ratio of condensing water to condensed steam at the given vacuum from Fig. X., multiply this by the steam used by the engine per hour, and by the horse-power per pound of water circulated, as above, and the result is the horse-power required.

To find the horse-power absorbed in pumping out the vacuum, we multiply the horse-power per pound of condensed steam of the "Bremen" air pump at 26 inches vacuum, as above, by the steam used by the engine per hour, and this product divided by the horse-power at the same vacuum from Fig. VI. gives a constant which, when multiplied by the horse-power from Fig. VI. at any vacuum, gives the horse-power absorbed by the vacuum pump at that vacuum. This figure added to the horse-power of the circulating pump, and multiplied by the B. T. U. equivalent to 40 pounds steam, gives the B. T. U. per hour absorbed by the pump, corresponding to column 3 of Table VII., which we call "*b*."

The total heat supplied to the engine (*a*), and the heat returned in the feed water (*c*), are found as before—Table VII., column 4—using the same curve of temperature in condenser, Fig. VII. The column of horse-powers is found as in Table VI., column 5, using the proper curve from Fig. IX., and this column, divided into the column of "$a - b - c$," gives the B. T. U. per hour per horse-power.

COMPUTATION FOR BRISTOL ENGINE.

An average of 10 cards from the Harris-Corliss engine shows that at 25.6 inches of vacuum, 11.15 pounds was realized on the

cards (see Table IX.). This point was laid off at B, Fig. IX., and the curve drawn as already described. The calculation of the B. T. U. per hour per horse-power was made as above, and the results entered in Tables X. and XI. In finding "*a*," the total heat supplied to engine, the heat required to superheat the steam was added to the total heat found from the steam table, as shown at the bottom of Table XI. The final result, Table XI., column 9, is plotted in the curve A A A, Fig. III. This curve, like that for the Buckeye engine, Fig. II., shows a minimum at 25 inches of vacuum.

In calculating the B. T. U. per hour per horse-power with pump driven directly by the main engine, the total B. T. U. absorbed—column 10, Table XI.—was found by subtracting the B. T. U. returned in the boiler feed—column 7, Table XI.—from the total B. T. U. in the steam fed to the engine—(*a*). This figure, divided by the horse-power of the engine—column 5, Table X.—gave the B. T. U. per hour per horse-power, column 11, Table XI. This column gives the curve B B B, Fig III., which shows a minimum at 26½ inches of vacuum.

COMPUTATION FOR PAWTUCKET ENGINE.

In examining the cards from the Pawtucket engine, it was found that the drop between the cylinder and the condenser was so small as to be barely appreciable, which is natural, considering the slow piston speed and large ports of the engine. The back-pressure curve, Fig. IX., was therefore assumed to be the theoretical one for a perfect steam-exhaust line or to be the straight line in the figure. The calculations are shown in Tables XII. and XIII., and the final curves in Fig. IV. The curve A A A, of economy with an independent vacuum and circulating pump, shows a minimum at 26.5 inches of vacuum, or 1.5 inches more than for the Harris–Corliss engine. The curve B B B shows a minimum at 28 inches of vacuum, which is also 1.5 inches more than for the Harris-Corliss engine under similar conditions.

The difference between the results for the two engines is mainly due to the fact that there is a less loss of pressure produced by the friction of the steam in the exhaust passages in the Pawtucket than in the Harris–Corliss engine.

TABLE I.—*Data of Test No. 3. May 21, 1895.*

Time.	No. of Card.	Reading of Revolution Counter Attached to Engine.	Meter Reading.	Weight of Condensed Steam from Engine in Pounds.	Vacuum in Inches of Mercury.	Temperature of Condensed Steam in Degrees Cent.	Temperature of Condensing Water Leaving Condenser, in Degrees Cent.	Boiler Pressure, Pounds per Square Inch Above Atmosphere.	Weight of Condensed Steam from Pump in Pounds.	Pressure of Steam at Pump in Pounds per Square Inch Above Atmosphere.	Temperature of Steam at Pump in Degrees Cent.	Reading of Revolution Counter Attached to Pump.
1	2	3	4	5	6	7	8	9	10	11	12	13
10.10	163	40031	737.	90.	26.6	42.	26	75	100.	24	143.	5341
10.20	164	41985	789.7	164.5	27.05	43.	26	76	110.75	24	143.	5454
10.30	165	43901	844.7	239.5	26.9	44.	26	76	122.	24	142.	5556
10.40	166	45780	899.2	317.5	26.9	46.5	27	75	133.5	24	142.	5670
10.50	167	47717	957.	395.	26.85	44.	26	77	145.5	24	142.	5780
11.00	168	49688	1012.	474.	26.65	44.	26	75	157.	25	143.	5887
11.10	169	51635	1067.8	168.5*	26.75	46.	27	81	168.5	25	143.	5991
11.20	170	53530	1120.8	247.	26.65	45.	27	83	180.	25	144.	6091
11.30	171	55461	1176.8	324.5	26.80	44.	26	82	191.25	25	143.5	6195
11.40	172	57394	1234.5	401.5	26.75	43.5	27	71	203.5	25	142.5	6304
Average,		192.92 revs. per minute.	5.53 cu. ft. per minute.	463.6 lbs. per hour.	26.82	44.2	26.4	77.1	69 lbs. per hour.	24.5	142.8	10.7 revs. per minute.

Pressure of steam at engine, 15 pounds per square inch above atmosphere.
Temperature of condensing water entering condenser, 14.4° Cent.
Barometer, 30.22 inches.
* Initial weight of barrel = 90 lbs.

TABLE II.—*Synopsis of Data of Tests.*

Date.	Duration in Hours and Minutes.	Vacuum in Inches of Mercury.	Temperature of Condensed Steam in Degrees Fahr.	Barometer.	Pressure at Engine in Pounds per Square Inch Above Atmosphere.	Revolutions per Minute of Engine.	Water per Hour from Engine in Pounds.	Cubic Feet of Condensing Water per Minute.	Temperature of Condensing Water in Degrees Fahr.		Boiler Pressure in Pounds per Square Inch Above Atmosphere.	Pressure of Steam at Pump in Pounds per Square Inch Above Atmosphere.	Temperature of Steam at Pump in Degrees Fahr.	Superheating in the Steam at Pump in Degrees Fahr.	Revolutions of Pump per Minute.
									Entering Condenser.	Leaving Condenser.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. May 16...	1½ h.	27.	107.35	29.95	15	193.67	497.66	5.84	59.9	80.7	75.1	26.	288.	19.7	11.15
2. May 17...	1 h. 10 m.	27.06	108.8	30.19	15	193.2	512.	5.8	59.	80.2	75.8	26.	287.	18.7	11.24
3. May 21...	1½ h.	26.82	111.5	30.22	15	192.92	463.6	5.53	57.9	79.5	74.1	25.5	289.	21.5	10.70
4. May 2...	1 h. 40 m.	26.7	110.3	30.31	15	202.24	479.4	4.85	59.9	80.	75.5	26.77	286.7	17.3	8.61
5. May 10...	2 h.	26.31	115.5	29.93	15	193.75	477.25	5.53	64.4	85.7	71.	25.	285.8	18.8	11.17
6. May 8...	1 h. 50 m.	26.28	116.25	30.10	15	192.85	480.54	4.807	61.7	85.8	81.5	26.3	286.4	17.7	10.86
7. May 6...	1 h. 50 m.	26.15	119.5	30.36	15	193.2	456.6	4.21	60.8	86.2	66.6	33.	282.6	4.6	10.30
8 May 13...	1 h. 40 m.	25.63	114.9	30.03	15	189.28	488.1	4.82	64.4	88.8	67.7	31.	284.4	9.4	9.24
9. May 7...	1 h. 40 m.	25.1	129.2	30.23	15	193.8	459.	3.403	60.8	93.7	72.66	26.	285.2	16.9	10.86
10. May 20...	1½ h.	24.55	133.2	30.15	15	194.2	478.8	2.99	57.6	99.1	79.2	24.	286.	21.	10.58
11. May 22...	1½ h.	23.9	137.	30.2	15	194.41	451.66	2.71	57.7	100.2	71.4	24.4	281.7	15.9	10.51
12 May 23...	1½ h.	22.92	140.9	30.18	15	193.15	456.4	2.46	57.6	102.	75.5	26.	284.	15.7	10.69
13 May 27...	1¼ h.	22.02	147.4	29.94	15	192.76	454.3	2.28	61.2	109.2	74.7	26.	284.	15.7	10.25
14 May 29...	50 m.	20.97	152.4	30.07	15	197.04	457.8	2.14	61.7	114.3	76.	18.7	285.6	28.9	10.30
15. May 31*a*..	1½ h.	20.02	158.9	29.96	15	192.54	420.	1.81	64 4	121.5	75.1	23.7	284.5	19.5	10.24
16. May 31 *b*.	1 h.	18.05	166.2	29.96	15	192.73	416.	1.56	65.1	131.5	75.3	21.	282.6	22.	7.03
17. May 31*c*..	1 h.	15.44	174.2	29.96	15	193.7	397.	1.33	65.3	141.8	76.8	18.	279.9	24.5	7.05

TABLE III.—*Calculation of Horse-Power of Engine from Indicator Cards. Test No. 3. May 21, 1895.*

No. of Card.	Maximum Vacuum Realized on Card in Pounds per Square Inch Below Atmosphere. Measured on 20 Scale.			Areas of Indicator Cards, in Square Inches, each Card Measured by Two Parties.					
				Head End.			Crank End.		
	Head.	Crank.	Average.	No. 1	No. 2	Average.	No. 1	No. 2	Average.
1	2	3	4	5	6	7	8	9	10
163	10.8	10.8	10.8	2.84	2.85	2.845	3.08	3.10	3.09
164	11.	10.8	10.9	2.89	2.90	2.895	3.13	3.16	3.145
165	10.8	10.7	10.75	2.93	2.96	2.945	3.19	3.21	3.20
166	10.6	10.5	10.55	2.91	2.91	2.91	3.18	3.18	3.18
167	10.8	10.6	10.7	3.06	3.05	3.055	3.14	3.17	3.155
168	10.7	10.6	10.65	2.96	2.96	2.96	3.15	3.15	3.15
169	10.8	10.6	10.7	2.92	2.93	2.925	3.16	3.18	3.17
170	11.	10.75	10.9	2.98	2.99	2.985	3.15	3.15	3.15
171	10.8	10.6	10.7	2.92	2.94	2.93	3.10	3.11	3.105
172	10.7	10.6	10.65	2.98	2.99	2.985	3.18	3.20	3.195
Average,			10.73			2.9435			3.154

Actual vacuum realized (true scale of spring = 20.3) = $10.73 \times \frac{20.3}{20}$ = 10.89. Length of card = 3.75".

M. E. P. of head end = $\frac{20.3 \times 2.9435}{3.75} = 15.93$.

M. E. P. of crank end = $\frac{20.3 \times 3.154}{3.75} = 17.07$.

Area of piston = 40.041 square inches.

Area of rod = .994 square inch.

H. P. of head end = $\frac{40.041 \times 15.93 \times 14 \times 192.92}{12 \times 33000} = 4.35$

H. P. of crank end = $\frac{(40.041 - .994) \times 17.07 \times 14 \times 192.92}{12 \times 33000} = 4\ 54$

Total H. P. = 8.89.

TABLE IV.—*Synopsis of Indicator Cards from Engine.*

Number of Test.	Vacuum Realized.	M. E. P., Head End.	M. E. P., Crank End.	Total H. P.	Water per Hour per I. H. P.
1	2	3	4	5	6
1	10.60	17.15	16.64	9.15	54.4
2	10.82	17.06	16.78	9.13	56.0
3	10.89	15.93	17.07	8.89	51.2
4	10.89	16.72	16.09	9.27	51.7
5	10.81	16.93	16.30	8.99	53.2
6	10.83	17.19	16.13	8.975	53.6
7	10.99	16.86	16.58	9.035	50.5
8	10.68	17.26	16.37	8.89	54.9
9	10.60	16.59	15.72	8.75	52.5
10	10.307	15.69	16.82	8.81	54.3
11	10.10	15.38	16.3	8.60	52.5
12	9.88	15.1	16.1	8.43	54.2
13	9.45	15.22	16.10	8.43	54.9
14	9.16	13.7	15.77	8.1	56.6
15	8.82	13.40	15.37	7.73	54.4
16	8.	12.98	14.88	7.49	55.5
17	6.8	11.96	14.	7.01	56.7

Average col. 2 = 9.978.

TABLE V.—*Synopsis of Indicator Cards from Pump.*

No. of Test.	M. E. P. Head.	M. E. P. Crank.	I. H. P.	Fric. H. P. = N. .00505	Net I. H. P.	Excess of Water	H. P. Eq. to Pump Excess.	Net H. P. Corrected for Excess.
1	2	3	4	5	6	7	8	9
1	7.00	7.09	.1295	.0563	.0732	78	.0012	.0720
2	7.47	6.85	.1327	.0568	.0759	92	.0014	.0745
3	7.12	6.63	.1214	.0540	.0674	44	.00067	.0667
4	8.12	8.27	.1164	.0435	.0729	59	.0009	.0780
5	7.90	7.86	.1451	.0564	.0887	57	.00086	.0878
6	7.46	7.48	.1337	.0548	.0789	61	.00091	.0780
7	7.95	6.92	.1265	.0520	.0745	37	.00055	.0740
8	8.59	9.17	.1352	.0467	.0885	68	.001	.0875
9	7.94	7.08	.1342	.0548	.0794	39	.00056	.0788
10	7.1	6.69	.1203	.0534	.0669	59	.00083	.0661
11	6.7	7.04	.1190	.0531	.0659	32	.00044	.0655
12	7.02	6.5	.1194	.0540	.0654	36	.00047	.0649
13	7.11	6.38	.1142	.0518	.0624	34	.00043	.0620
14	6.675	6.35	.1107	.0520	.0587	38	.0004	.0583
15	6.74	5.89	.1069	.0517	.0552	00	00	.0552
16	7.23	6.52	.0799	.0355	.0444	—4	00	.0444
17	7.12	6.44	.0789	.0356	.0433	—23	—.0002	.0435

TABLE VI.—*Calculation of Indicated Horse-Power of Engine that will Make the Results Conform to an Average Curve.*

No. of Test.	Actual M. E. P Head and Crank Average.	Vacuum Realized from Curve. Fig. V., = P.	M. E. P. = 5.85 + P = $P^{1.6}$	Total H. P. High and Low Cyls. = $\frac{(P^1 + 16) \times 23.1035}{16.78 + 16}$
1	2	3	4	5
1	16.89	10.93	16.78	23.1035
2	16.92	10.94	16.79	23.0965
3	16.50	10.91	16.76	23.0822
4	16.41	10.88	16.73	23.0614
5	16.62	10.82	16.67	23.0191
6	16.66	10.81	16.66	23.0120
7	16.72	10.78	16.63	22.9912
8	16.82	10.66	16.51	22.9060
9	16.16	10.53	16.38	22.8150
10	16.26	10.38	16.23	22.7091
11	15.84	10.18	16.03	22.5684
12	15.60	9.88	15.73	22.3571
13	15.66	9.55	15.40	22.1247
14	14.74	9.15	15.00	21.8426
15	14.39	8.78	14.63	21.5826
16	13.93	7.96	13.83	21.0197
17	12.98	6.83*	12.68	20.2072

Average, 15 83.

15.83 — 9 98 (col. 2, IV.) = 5.85 = equivalent M. E. P. for zero vacuum.

* This method makes results fit the average curve for the measurements of actual M. E. P. given in col. 2.

TABLE VII.—*Calculation of B. T. U. per Hour per Indicated Horse-Power of Engine.*

No. of Pt. on Curve, Fig. II.	H. P. of Pump from Curve, Fig. VI.	B. T. U. Absorbed by Pump per Hour at 40 Lbs. of Water Consumed per Hour per H.P.	B. T. U. Returned in Boiler Feed per Hour.	Total B. T. U. Absorbed per Hour = *a* + Col. 3 — Col. 4.	Total B. T. U. per Hour per I. H. P. of Engine.
1	2	3	4	5	6
1	.0790	3750	31000	471720	20426
2	.0792	3760	30800	471920	20432
3	.0784	3720	32000	470680	20391
4	.0780	3700	32580	470080	20384
5	.0767	3640	34600	468000	20331
6	.0766	3640	34650	467950	20335
7	.0761	3620	35250	467330	20326
8	.0743	3530	37650	464840	20293
9	.0724	3440	39730	462670	20279
10	.0704	3310	41790	460510	20279
11	.0684	3250	43700	458510	20316
12	.0653	3110	46120	455950	20394
13	.0620	2950	48500	453410	20493
14	.0583	2770	50800	450930	20645
15	.0552	2620	52700	448880	20798
16	.0484	2300	56300	444960	21169
17	.0396	1880	60000	440840	21816

a = total B. T. U. in 420 pounds of steam at 135 pounds absolute = 498960 B. T. U.

TABLE VIII.—*Ratio of Condensing Water to Steam.*

No. of Point on Curve, Fig. II.	Vacuum.	Rise in Temperature of Condensing Water in Degrees Fahrenheit.	Increase in Temperature of Condensing Water in Degrees Fahrenheit if Final Temperature were that Observed During Test and Initial Temperature were 60° Fahr.	Cubic Feet Condensing Water Used per Minute Corresponding to Initial Temperature of 60° Fahr. = Actual Cubic Feet per Minute × Col. 3 / Col. 4	Steam Used by Engine in Pounds per Hour.	Ratio of Condensing Water to Steam Condensed.
1	2	3	4	5	6	7
1	27.00	20.8	20.7	5.87	497.7	44.2
2	27.06	21.2	20.2	6.08	512.0	44.5
3	26.82	21.6	19.5	6.12	463.6	49.4
4	26.70	20.1	20.0	4.88	479.4	38.2
5	26.31	21.3	25.7	4.58	477.25	36.0
6	26.28	24.1	25.8	4.49	480.5	35.0
7	26.15	25.4	26.2	4.08	456.6	33.5
8	25.63	24.4	28.8	4.08	488.1	31.3
9	25.10	32.9	33.7	3.32	459.0	27.1
10	24.55	41.5	39.1	3.17	478.8	24.8
11	23.90	42.5	40.2	2.87	451.7	23.8
12	22.92	44.4	42.0	2 60	456.4	21.35
13	22.02	48.0	49.2	2.22	454.3	18.30
14	20.97	52.6	54.3	2.07	457.8	16.9
15	20.02	57.1	61.5	1.68	420.0	15.0
16	18.05	66.4	71.5	1.45	416.0	13.07
17	15.44	76.5	81.8	1.24	397.0	11.71

TABLE IX.—*Measurements of Cards of Harris-Corliss Engine.*

DISTANCE OF BACK-PRESSURE LINE BELOW ATMOSPHERIC LINE.

No.	Head End. Spring B.	Crank End. Spring A.	Number.	Head End. Spring A.	Crank End. Spring B
1	.69	.52	6	.52	.69
2	.69	.54	7	.54	.68
3	.68	.52	8	.53	.69
4	.69	.54	9	.53	.68
5	.69	.51	10	.52	.68
Average,	.688	.526	Average,	.528	.684

Scale, Spring A = 20.9.
Scale, Spring B = 17.01.
Average distance for cards taken with Spring A = .527 inch.
Vacuum realized in cylinder by Spring A = 11.01 pounds per square inch.
Average distance for cards taken with Spring B = .686 inch.
Vacuum realized in cylinder by Spring B = 11.29 pounds per square inch.
Average vacuum realized from cards = 11.15 pounds per square inch.
Vacuum in condenser = 25.6 inches.

TABLE X.—*Calculation of Indicated Horse-Power of Harris-Corliss Engine Corresponding to Various Vacuums.*

Point No.	Vacuum in Inches of Mercury.	Vacuum Realized from Curve in Lbs. per Sq. Inch.	M. E. P. for Varying Back Pressure and Constant Area Above Atm. Line. 16.31 + Col. 3.	I. H. P. for Varying Back Pressure and Constant Area of Indicator Cards Above Atm. Line.
1	2	3	4	5
1	16	7.28	23.59	1367.4
2	17	7.73	24.04	1393.5
3	18	8.17	24.48	1419.2
4	19	8.62	24.93	1445.4
5	20	9.04	25.35	1469.5
6	21	9.46	25.77	1493.9
7	22	9.87	26.18	1517.4
8	23	10.26	26.57	1540.3
9	23.5	10.45	26.76	1551.2
10	24	10.63	26.94	1561.4
11	24.5	10.82	27.13	1572.4
12	25	10.97	27.28	1580.9
13	25.5	11.15	27.46	1591.6
14	26	11.27	27.58	1598.2
15	26.5	11.42	27.73	1607.4
16	27	11.53	27.84	1613.9

DATA OF TEST EMPLOYED IN CALCULATING RESULTS GIVEN IN TABLE IX.

Indicated horse-power = 1592.2.

M. E. P. (low cylinder + equivalent of high-pressure cylinder) = 27.46 pounds per square inch.

Boiler pressure = 123 pounds per square inch.

Average superheating = 14.6° Fahr.

Vacuum = 25.6 inches of mercury.

Vacuum realized on cards = 11.15 pounds per square inch.

Equivalent M. E. P. for zero vacuum = 27.46 — 11.15 = 16.31 pounds per square inch.

Steam consumption in pounds per hour = 21500.

TABLE XI.—*Calculation of B. T. U. per Hour per Horse-Power for Harris Corliss Engine.*

Point No.	Vacuum.	Horse-Power.			Total B. T. U. Absorbed by Combined Circulating and Vacuum Pump per Hour at 40 Lbs. of Steam per Hour per H. P.	B. T. U. Returned in Boiler Feed per Hour.	Total B. T. U. Absorbed per Hour = A + Col. 6 − Col. 7.	B. T. U. per Hour per I. H. P.* Col. 8 ÷ Col. 5, Table X.	Total B. T. U. Absorbed per Hour, Pump Driven Direct by Engine. A − Col. 7.	B. T. U. per Hour per Total I. H. P. of Engine.† Col. 10 ÷ Col. 5 Table X.
		Air Pump.	Circulating Pump.	Total.						
1	2	3	4	5	6	7	8	9	10	11
1	16	1.843	5.31	7.153	342000	3030000	23026000	16839	22684000	16591
2	17	1.996	5.62	7.616	364000	2960000	23118000	16590	22754000	16329
3	18	2.190	5.97	8.16	390500	2880000	23224500	16365	22884000	16089
4	19	2.298	6.39	8.688	415500	2794000	23335500	16145	22920000	15857
5	20	2.450	6.9	9.35	447000	2700000	23461000	15965	23014000	15661
6	21	2.6	7.52	10.12	484000	2600000	23598000	15790	23114000	15472
7	22	2.752	8.27	11.022	527000	2486000	23755000	15655	23228000	15307
8	23	2.906	9.2	12.106	579500	2360000	23933500	15538	23354000	15161
9	23.5	2.984	9.95	12.934	618000	2292000	24040000	15498	23422000	15092
10	24	3.06	10.52	13.58	649000	2220000	24143000	15462	23494000	15046
11	24.5	3.134	11.36	14.494	692500	2136000	24270500	15435	23578000	14995
12	25	3.210	12.26	15.47	740000	2050000	24404000	15437	23664000	14968
13	25.6	3.284	13.57	16.854	806000	1952000	24568000	15436	23762000	14929
14	26	3.362	14.68	18.042	863000	1842000	24735000	15477	23872000	14936
15	26.5	3.440	16.4	19.84	949000	1718000	24945000	15519	23996000	14928
16	27	3.552	19.15	22.702	1085000	1586000	25213000	15622	24128000	14950

A = B. T. U. per hour = 21500 × 1196 = 25714000, where 1196 = total heat from 32° F. + heat due to 14.6° superheating.

* Indicated horse-power is that of engine and does not include power of pump.

† Indicated horse-power in this case includes power required to drive vacuum pump.

TABLE XII.—*Calculation of I. H. P. of Pawtucket Pumping Engine for Various Vacuums.*

No. of Point in Curve.	Vacuum.	Vacuum Realized from Curve, Lbs. per Sq. Inch.	M. E. P. for Varying Back-Pressure Line and Constant Area Above Atm. Line = Col. 3 + 13.66.	Indicated Horse-Power for Varying Back Pressure and Constant Area of Indicator Cards Above Atm. Line.
1	2	3	4	5
1	16	7.85	21.51	111.3
2	17	8.33	21.99	113.9
3	18	8.83	22.49	116.5
4	19	9.33	22.99	119.1
5	20	9.82	23.48	121.6
6	21	10.31	23.97	124.1
7	22	10.80	24.46	126.7
8	23	11.29	24.95	129.2
9	23.5	11.54	25.20	130.5
10	24	11.79	25.45	131.8
11	24.5	12.03	25.69	133.0
12	25	12.27	25.93	134.2
13	25.5	12.53	26.19	135.6
14	26	12.77	26.43	136 9
15	26.5	13.03	26.69	138.2
16	27	13.26	26.92	139.4
17	27.5	13.50	27.16	140.6
18	28	13.76	27.42	141.9
19	28.5	14.00	27.66	143.2

DATA OF TEST EMPLOYED IN CALCULATING RESULTS GIVEN IN TABLE XIII.

M. E. P. reduced to low-pressure cylinder = 27.02 pounds per square inch.

H. P. = 139.95.

Vacuum = 27.2 inches of mercury.

Water per hour = 2012.6 pounds.

Boiler pressure = 124 pounds per square inch.

Barometer = 30.07 inches.

Vacuum realized on card = 13.36 pounds per square inch.

Equivalent M. E. P. for zero vacuum = 27.02 — 13.36 = 13.66 pounds per square inch.

* *Transactions* American Society Mechanical Engineers, Vol. XI., p. 328.

TABLE XIII.—*Calculation of B. T. U. per Hour for the Pawtucket Engine.*

No. of Points.	Vacuum in Inches.	Horse Power.			B. T. U. Absorbed by Combined Circulating and Vacuum Pump per Hour at 40 Lbs. of Steam per Hour per H. P.	B. T. U. Returned in Boiler Feed per Hour.	Total B. T. U. Absorbed per Hour = A + Col. 6 − Col. 7.	B. T. U. per Hour per I. H. P. Col. 8 ÷ Col. 5 Table XII.*	Total B. T. U. Absorbed per Hour, Pump Driven Direct by Engine. A − Col. 7.	B. T. U. per Hour per Total I. H. P. of Engine.† Col. 10 ÷ Col. 5. Table XII.
		Air Pump.	Circulating Pump.	Total.						
1	2	3	4	5	6	7	8	9	10	11
1	16	.1725	.497	.6695	31840	283700	2140940	19236	2109100	18949
2	17	.1869	.526	.7129	33900	277000	2149700	18874	2115800	18664
3	18	.2052	.559	.7642	36300	269600	2159500	18537	2123200	18225
4	19	.2154	.598	.8134	38650	261500	2169950	18219	2131300	17895
5	20	.2294	.646	.8754	41600	253000	2181400	17939	2138800	17588
6	21	.2438	.704	.9478	45050	243400	2194450	17683	2149400	17319
7	22	.258	.774	1.032	49100	232800	2209100	17436	2160000	17048
8	23	.272	.862	1.134	53900	221000	2225700	17227	2171800	16809
9	23.5	.2794	.921	1.2004	57050	212600	2237250	17144	2180200	16707
10	24	.2865	.986	1.2725	60500	207800	2245500	17037	2185000	16578
11	24.5	.2936	1.064	1.3576	64500	200000	2257300	16972	2192800	16487
12	25	.3005	1.149	1.4495	68900	192000	2269700	16913	2200800	16399
13	25.5	.3078	1.251	1.5588	74100	182700	2284200	16845	2210100	16297
14	26	.3148	1.375	1.6898	80350	172400	2300750	16806	2220400	16219
15	26.5	.322	1.536	1.858	88300	160900	2320200	16788	2231900	16150
16	27	.2228	1.792	2.1208	100800	148400	2345200	16824	2244400	16100
17	27.5	....	....	....	....	133400	....	....	2259400	16070
18	28	....	....	....	....	115300	....	..	2277500	16050
19	28.5	....	....	....	....	93600	....	....	2299200	16056

$A = 2012.6 \times 1188.9 = 2392800$ B. T. U.

* Indicated Horse-Power is that of the engine and does not include power of pump.
† Indicated Horse-Power in this case includes power to drive vacuum pump.

MECHANICAL INTEGRATORS.

BY PROF. J. BURKITT WEBB.

POLAR TRACTRIX.

(*Continued.*)

The words "Pushing" and "Pulling" in Fig. 43 refer to the generation of the outer branches of the curve. The Differential Equation of the Tractrix shows that when β exceeds β_0 $d\gamma$ is minus when $d\beta$ is plus. It may therefore be supposed that when the right-hand outer branch reaches infinity and β approaches the value β_0 with a velocity which has become infinitesimal, this velocity carries the Measuring-Bar beyond β_0. This reverses the value of $d\gamma$, and starts the Stylus upon the inner right-hand branch, which is then traced with a continuously increasing β but decreasing γ, the Measuring-Bar being pushed along until γ is again o and β reaches $180°$. Then the inner left-hand branch is traced by pulling the Measuring-Bar while β increases to $360° - \beta_0$ and γ decreases to $-\infty$, when the four branches of the curve will have been traced continuously, as indicated by the arrowheads, Fig. 44, the Measuring-Bar overstepping again by an infinitesimal, so as to change the sign of $d\gamma$ and start again upon the upper left-hand branch.

If the curve be regarded as a path already laid out which the Stylus must follow, and β be looked upon as the continually increasing independent variable, it compels its function γ to oscillate from minus to plus infinity and back with every increase of 2π in β. Viewing this arrangement as a mechanism, if the Measuring-Bar be rotated uniformly, the Radius-Bar oscillates with a fast and slow motion, which for $\beta_0 = 90°$ becomes a hyperbolic cosine, or secant, motion, the inverse of the crank, or ordinary cosine, motion.

This is shown by substituting $\nearrow \beta_0 = o$ in the Differential Equation of the Tractrix and dividing by dt to reduce it to the velocity equation

$$\frac{d\gamma}{dt} = \angle\beta \cdot \frac{d\beta}{dt}$$

The signs used for the trigometrical functions are, as previously explained, $\wedge$, $\nearrow$, $\lrcorner$, Γ, $\angle$ and $\vee$ for sine, cosine, tangent, cotangent, secant and cosecant.

NON-ROLLING CURVES.

With the Polar Tractrix as a basis it is easy to lay out any *Non-rolling Curve*, or curve traced by the Stylus A at a distance a from V. In fact, as the Equation of the Polar Tractrix is an equation between β and γ, it is also the equation of the whole series of Non-rolling Curves, each one being perfectly defined by the supplementary equation,

$$a = a_1 b$$

Thus there are three parameters, of which b may be called the parameter of size, while c and a_1 govern the shape. For the Polar Tractrix $a_1 = 1$, while for the Non-rolling Curves it may have any other value from $-\infty$ to $+\infty$. Each of these curves has its own asymptote or o-Circle traced by the Stylus A when $\beta = \beta_0$, and of all these circles that belonging to the Polar Tractrix is the least.

The existence of these curves was first called to the writer's attention by Sir ROBERT BALL'S suggestion thereof; see Williamson's Integral Calculus, page 216.

COMMON TRACTRIX.

When c becomes infinite the Polar Tractrix degenerates into the Common Tractrix, Fig. 44, with the equation

$$y + b \wedge \beta = b \cdot lg \pm \lrcorner \tfrac{1}{2}(90^\circ + \beta),$$

which becomes, when put in form for laying out the curve in the manner employed in Fig. 43,

$$y + b \wedge \beta = \frac{b}{\cdot 4343}\, lg_{10}\, \frac{Chord\,(90^\circ + \beta)}{Chord\,(90^\circ - \beta)},$$

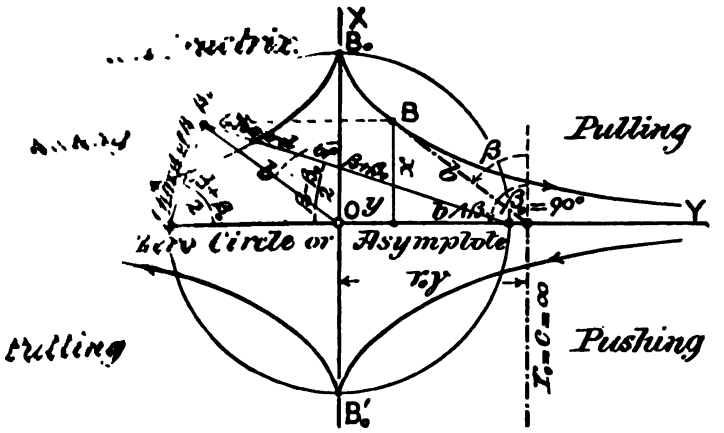


FIGURE 44.

it being evident from the figure, or otherwise, that the tangent of the half-angle is the ratio of these chords.

As to the left-hand member of the equation of the Polar Tractrix,

$$-\lrcorner\beta_0 \cdot \gamma = lg \pm \frac{\wedge\frac{1}{2}(\beta_0+\beta)}{\wedge\frac{1}{2}(\beta_0-\beta)},$$

$$-\lrcorner\beta_0 \cdot \gamma = \frac{r_0\gamma}{b};$$

where $r_0\gamma$ is the arc of the o-Circle from the origin O to the Radius-Bar, or in Fig. 44 the rectilinear arc OV of the now infinite o-Circle, which is seen to have the value $y+b\wedge\beta$. In the right-hand member $\beta_0=90°$, when c becomes infinite, and the fraction reduces easily to the half-tangent. Or, otherwise,

$$\frac{\wedge\frac{1}{2}(90°+\beta)}{\wedge\frac{1}{2}(90°-\beta)} = \sqrt{\frac{1-\nearrow(90°+\beta)}{1-\nearrow(90°-\beta)}} = \sqrt{\frac{1+\wedge\beta}{1-\wedge\beta}} = \sqrt{\frac{b+\surd(b^2-x^2)}{b-\surd(b^2-x^2)}}$$

because $\quad b\nearrow\beta = x$

and therefore $\quad b\wedge\beta = \surd(b^2-x^2)$.

This leads to the *Rectangular Equation of the Tractrix*

$$y = \tfrac{1}{2}b \cdot lg\frac{b+\surd(b^2-x^2)}{b-\surd(b^2-x^2)} - \surd(b^2-x^2),$$

or, putting $y \div b = y_1$, and $x \div b = x_1$

$$y_1 = \tfrac{1}{2} lg \frac{1+\sqrt{(1-x_1^2)}}{1-\sqrt{(1-x_1^2)}} - \sqrt{(1-x_1^2)}$$

an equation of pure form including, therefore, all sizes of the curve.

SECOND FORM OF THE CURVE.

The curve shown in Fig. 43 is the form originally obtained for the Polar Tractrix, and is that corresponding to the usual proportions of a planimeter, b being usually made less than c. Such a treatment lacks somewhat in generality, to remedy which a discussion of the second, and further discussion of the first form of the curve will now be added. Second form curves are shown in Figs. 45, 46, and 47.

The equation already produced is, however, perfectly general, and it is only necessary to regard β_0 as the complex arc or quantity whose

$$\angle \beta_0 = -\frac{b}{c},$$

where b is now greater than c so that the cosine no longer lies between $+1$ and -1, to be able to calculate, by the calculus of complex quantities, a single real value of γ for any real value of β.

In this way the second form of the curve can be drawn.

The Differential Equation of the Polar Tractrix may, however, be written

$$d\gamma = \frac{b\, d\beta}{b + c\angle \beta}$$

the integral of which can have the form

$$\lrcorner \frac{\sqrt{b^2-c^2}}{b} \cdot \tfrac{1}{2}\gamma = \sqrt{\frac{b-c}{b+c}} \lrcorner \tfrac{1}{2}\beta$$

where, for $\gamma = o$, $\beta = o$. The plus signs of the radicals are to be taken, as the minus signs give no additional meaning. Therefore one *Trigonometrical Equation of the Polar Tractrix* is

$$\lrcorner \tfrac{1}{2}\beta = \sqrt{\frac{b+c}{b-c}} \lrcorner \left(\frac{\sqrt{b^2-c^2}}{b} \cdot \tfrac{1}{2}\gamma \right)$$

which gives β as a real single valued function of γ.

Putting c_1 for $c \div b$, the parameter of form, this becomes

$$\angle \tfrac{1}{2}\beta = \frac{1+c_1}{1-c_1} \angle (\sqrt{1-c_1^2} \cdot \tfrac{1}{2}\gamma)$$

An inspection of the equation shows that both tangents must go through their zero and infinite values at the same times, when the angles will have the following pairs of values, in which $p = b \div \sqrt{b^2 - c^2} = \sqrt{\beta_0}'$;

$$\gamma = \quad 0 \quad p\pi \quad 2p\pi \quad 3p\pi \ldots\ldots\ldots np\pi$$
$$\beta = \quad 0 \quad \pi \quad 2\pi \quad 3\pi \ldots\ldots\ldots n\pi$$

Both β and γ will therefore increase simultaneously from $-\infty$ to $+\infty$, the average increase of β being equal to that of γ multiplied by $\angle \beta_0' = 1 \div p$.

The curve will therefore consist of an infinite number of right- and left-hand branches, each of which corresponds to an increase of π in β, or of 2π for a complete period or leaf. The periodic increase of γ is $2p\pi$, so that the angular width of a leaf is $2(p-1)\pi$, for although the Radius-Bar advances $2p\pi$, the Measuring-Bar retrogrades 2π with respect to it, leaving the difference as the real advance of the Stylus. The number of leaves in one turn is therefore $1 \div (p-1)$.

The number of times the curve encircles the centre c before repeating itself is given by the numerator of the fraction $p-1$ reduced to its lowest terms, the denominator being the corresponding number of leaves. In order that the repetition may occur after a single turn around the centre, p must have one of the following values:

$$p = \frac{2}{1} \quad \frac{3}{2} \quad \frac{4}{3} \quad \frac{5}{4} \ldots\ldots\ldots \frac{n+1}{n}$$
$$\textit{No. of leaves} = 1 \quad 2 \quad 3 \quad 4 \ldots\ldots\ldots n$$

The numerator of $p-1$ is here unity; by making it any other whole number a series of curves is arrived at, which repeat after that number of terms.

When c becomes infinitesimal the curve becomes an infinite number of infinitesimal leaves constituting a circle of

radius b. The reduction of the fraction $p-1$ to its lowest terms requires, of course, that both numerator and denominator be made whole numbers, and in this case both numerator and denominator will need to be multiplied by ∞, thus obtaining unity for the numerator.

CONSTRUCTION OF A CURVE.

The table shows that a curve of four leaves requires

$$p=\frac{5}{4}$$

or

$$=\frac{b}{\sqrt{b^2-c^2}}=\frac{5}{\sqrt{5^2-3^2}}$$

so that $c=3$ for $b=5$, or, calling b unity, $c=\frac{3}{5}$, and the equation becomes

$$\lrcorner\tfrac{1}{2}\beta=2\lrcorner\tfrac{3}{5}\gamma$$

and leads to the following table of values for the construction of Fig. 47.

TABLE OF β AND γ CO-ORDINATES.

Points.	γ	$2\lrcorner\frac{3}{5}\gamma$	β	$\gamma-\beta$
0	0°	0.	0	0
1	22° 30′	.317	35° 10′	−12° 40′
2	45°	.650	66° 00′	−21°
3	67° 30′	1.019	91° 10′	−23° 40′
4	90°	1.453	111° 00′	−21°
5	112° 30′	2.000	126° 50′	−14° 20′
6	135°	2.753	140° 00′	− 5°
7	157° 30′	3.925	151° 20′	6° 10′
8	180°	6.155	161° 30′	18° 36′
9	202° 30′	12.628	171° 00′	31° 30′
10	225°	∞	180° 00′	45°

The last column gives the inclination of the Measuring-Bar with respect to the X-axis. The table corresponds to the first right-hand branch. Only three points, 0, 6 and 10, are marked in the figure, 10 being indicated by B′, but 3 almost coincides with the point of inflection B_1.

FIGURE 47. POLAR TRACTRIX.

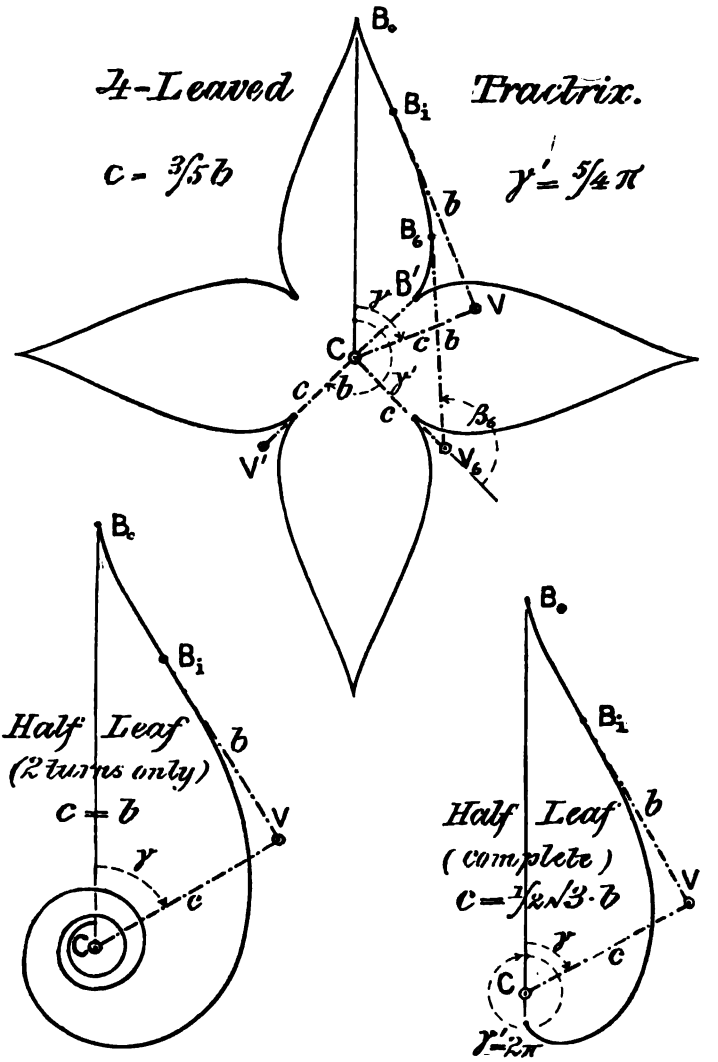


FIGURE 45. FIGURE 46.

It may be seen that

$$B_0C = \sqrt{b^2 - c^2},$$

but the radius of the o-Circle, here imaginary, is

$$r_0 = \sqrt{c^2 - b^2},$$

so that $r_0 = i \cdot B_0C,$

or $$B_0C = \frac{r_0}{i}$$

which gives $-.8$ as the area of the o-Circle, a value which can be found by interpolating for $c = \frac{3}{5}$ and $b = 1$ in Fig 15. Of course $i = \sqrt{-1}$.

Also, $$\frac{\sqrt{b^2 - c^2}}{b} = \frac{1}{p} = \Lambda\beta'$$

and $$\sqrt{\frac{b+c}{b-c}} = \Gamma\tfrac{1}{2}\beta',$$

β' being evidently the value of β, which makes $B_0C = r_0 \div i$.

The points of inflection of the curve correspond with $\beta = (n + \frac{1}{2})\ \pi$, while for the cusps $\beta = n\ \pi$.

Figures 45 and 46 show half leaves of other Traxtrices. When $c = b$ it takes an infinite number of turns to form a single leaf; this is the intermediate Tractrix between the first and second forms, and has *zero leaves* to a turn. A slight reduction of c gives the next tractrix with *one leaf* to a turn.

AREA OF THE POLAR TRACTRIX.

The area contained between any arc of the Polar Tractrix and the Zero-Circle, and terminated by two radii joining the extremities of the arc and the circle, may be found by subtraction if the expression be known for such an area, $B_0\ B\ Z_1\ O$, Fig. 49, commencing with the X-axis, or prime radius, and terminated by any other radius C B.

To produce such a formula, it is to be remarked that if the Stylus makes the circuit of this area in the direction B_0 B, etc., so that b times the Reading gives its value, the Wheel will not turn in passing over B_0 B and Z_1O, while for B Z_1 its motion will be negative, and for O B_0 positive.

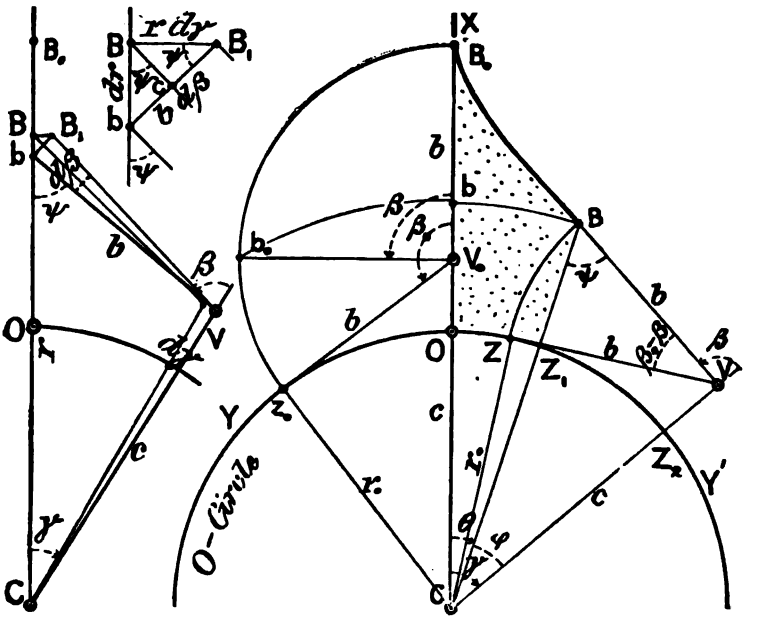


FIGURE 48. FIGURE 49.

The reading will therefore be due entirely to the passage of the Stylus from b to B_0, inasmuch as the readings for $B Z_1$ and O b will neutralize each other. It is therefore sufficient to produce an expression for the motion of the wheel when the Stylus is moved from any point b along the X-axis to B_0, where $\beta = o$.

Figure 48 leads to the differential equation

$$dR = -b \sin^2(\beta - \gamma)\, d\beta;$$

for with γ constant, let β decrease by $d\beta$, so that the Stylus moves the distance $b\, d\beta$ from b to B_1, then, with β constant, decrease γ by $d\gamma$, thus moving the Stylus from B_1 to B through a distance $r\, d\gamma$; these two motions are equivalent to a movement of the Stylus from b to B, a distance dr along the X-axis.

In the right-angled triangle $b B_1 B$, which is better shown in the enlarged view, B c is a perpendicular upon $b B_1$, cutting the triangle into two similar right-angled triangles, with angles

ψ equal to that of the triangle C b V, where $\psi = \beta - \gamma$. Now, as the Wheel, acting also as Stylus, moves obliquely from b to B it measures off on its circumference only that component of b B which is perpendicular to the Measuring-Bar. It therefore measures b c, the same as if it had moved to B by the path b c B, so that the differential increase of the Reading is

$$dR = \mathrm{bc} = \mathrm{bB}\,\Lambda\psi = \mathrm{bB}_1\,\Lambda^2\psi$$
$$= -b\,d\beta\,\Lambda^2\psi,$$

the minus sign being required because $d\beta$ is minus and dR plus.

From the triangle C b V

$$\Lambda\psi = c\,\Lambda\beta \div r$$

and

$$r^2 = b^2 + c^2 + 2bc\,\mathcal{J}\beta,$$

substituting which, there results

$$dR = -\frac{-b\,c^2\,\Lambda^2\beta\,d\beta}{b^2 + c^2 + 2bc\,\mathcal{J}\beta}$$

Dividing numerator and denominator by $2\,bc$, substituting $1 - \mathcal{J}^2\beta$ for $\Lambda^2\beta$ and putting B for $(b^2+c^2) \div 2bc$, B^2 being also added to and subtracted from the numerator, this reduces to the following expression, composed of terms in suitable form to be readily integrated,

$$dR = \frac{c\,\mathcal{J}\beta}{2}d\beta - \frac{cB}{2}d\beta + \frac{c}{2}\cdot\frac{B^2-1}{B+\mathcal{J}\beta}d\beta$$

b times the integral of which is, after replacing the value of B and reducing,

$$bR = \frac{bc}{2}\Lambda\beta - \frac{b^2+c^2}{4}\beta + \frac{b^2-c^2}{2}\lrcorner^{-1}\frac{b-c}{b+c}\lrcorner\tfrac{1}{2}\beta + const.$$

Substituting the superior limit $\beta = \beta$ and the inferior one $\beta = \beta$ and subtracting there results for the

Area of the Sector $\mathrm{B_0B\,Z_1O}$

$$A = \frac{c^2+b^2}{4}\beta - \frac{cb}{2}\Lambda\beta - \frac{c^2-b^2}{2}\lrcorner^{-1}\frac{c-b}{c+b}\lrcorner\tfrac{1}{2}\beta$$

which, as will be seen under the next heading, is equivalent to

$$A = \tfrac{1}{2}\,b^2\beta - \tfrac{1}{2}\,cb\,\Lambda\beta + \tfrac{1}{2}\,(c^2-b^2)\phi$$

(To be continued.)

ROENTGEN RAYS.

BY PRESIDENT HENRY MORTON, PH. D.

In connection with Dr. Roentgen's discovery and the X rays, there are a number of facts long known which in some cases seem to be forgotten, and which, while in no way detracting from the originality and merit of his discovery, yet need to be considered in order that the true characteristics of this discovery should be recognized, and the mixed or uncertain character of many experiments recently made by others in attempting to repeat or extend his results, clearly appreciated.

Thus to begin with, it is not new that invisible radiations obtained by electrical discharges in Geisler tubes and elsewhere, should produce photographic and fluorescent effects.

In the *American Journal of Art and Science*, 1864, Vol. 37, p. 207, will be found a paper by Prof. O. N. Rood, of Columbia College, entitled "On the Action of Very Weak Electric Light on the Iodized Plate." From this paper I will make a few quotations:

"About three years ago Dove received from Mr. Gunther, of Berlin, a photograph of a bronze statue of an Amazon holding a lance in a perpendicular position, Mr. G. at the same time calling his attention to a singular mark in the picture, which was not in the original."

"The lance was properly delineated on the negative plate, but in addition just at the tip, a dark streak was visible, though nothing of the kind had been observed at the time of taking the picture. Careful examination of the plate showed two other analogous marks. Dove thought that these singular appearances might have been caused by the presence of invisible electric brushes, resting on these points, and undertook some experiments to determine whether weak electric light could be photographed. Geisler tubes were used in a *dark* room and with the aid of Gunther he succeeded in obtaining good photographs of the stratified discharge."

Professor Rood then goes on to describe further experiments of his own, made to ascertain if these faint electric lights or discharges could be photographed in a *light* room and when they were invis-

ible to the eye. After describing some preliminary trials he further says: "Accordingly, to make an exact experiment on this point, a sheet of white paper was placed behind one of these" (Geisler) "tubes and white light reflected through it towards the camera. The intensity of this reflection was so regulated that the bright envelope of platinum wire" (in the tube) "was nearly invisible, and the diffused violet light at a greater distance from the wire, *absolutely* invisible. Nevertheless an intense photographic image of the envelope, and a very distinct image of the diffused electric light was easily obtained, thus proving conclusively the correctness of Dove's assumption that electric light, which in ordinary daylight could not be seen, owing to its feeble illuminating power, might yet make itself very evident on the iodized plate, by virtue of its high percentage of chemical rays."

The above is interesting as showing that as early as 1864 the relatively greater photographic than visual effect of the light produced in exhausted tubes (Geisler tubes) was recognized.

About the same time and thereafter and indeed up to the present day much work has been done in photographing that part of the solar spectrum which represents those vibrations which by reason of their short wave-length have either little effect upon the eye or none at all.

Prof. Wm. A. Miller* in London carried this work far enough to show that he could, by the use of quartz lenses and prisms, secure a photographic spectrum from the electric light extending beyond the visible violet for a distance several times as great as separated the extreme violet from the lowest visible red, at the other end of the visible spectrum. It was thus shown that *invisible* radiations of short wave-length possessed remarkable photographic power.

I will now turn to another line of observation which marks a limitation or distinction of the Roentgen effects in another direction.

When the eye is directed towards a faintly luminous object it will either at once perceive it (under favorable conditions) or not at all. In other words, nothing will be gained by continually gazing at it.

On the contrary, the best chance of catching sight of a faint object, such as a feebly luminous comet, is to look away from the

* See *Phil. Trans.* of Royal Society, 1862.

true direction and then, with some quickness, to turn the eyes towards it. In this way we can often secure a momentary impression of a dim object which we cannot perceive continuously.

With the sensitive photographic plate, however, all this is reversed.

An amount of light which, acting on a plate for one second, produces no sensible impression will produce a strong one if its action is continued for twenty or thirty seconds, and so on up to several hours of exposure.

One of the most interesting illustrations of this has been furnished in connection, with the photographing of stars carried on at the Harvard Observatory, under the Henry Draper Memorial, maintained by Mrs. Henry Draper, of New York; but the first observation of this phenomenon was made by Mr. A. A. Common, of England, in connection with his beautiful photograph of the nebula in Orion.

It was there found that, besides the impressions of visible stars on plates exposed for a long time, there were many other similar spots or images occurring time after time, in the same positions on successive plates, which were due to stars too faint to be perceived by the eye, but yet capable, by prolonged action, of producing images on the sensitive plates.

We see, then, that the photographic plate has yet another means of *seeing in the dark*, besides that due to its power of perceiving vibrations whose wave-length is too short to affect the nerves of the retina. By its *accumulative* action or capacity of *storing up* the effects of any sort of vibrations capable of affecting it, rays too feeble to affect the eye will, in time, impress the sensitive film.

There is yet another region of observation which should be marked off in order to appreciate fully the nature of the Roentgen discovery.

When in August of 1880, D. A. G. Bell announced his remarkable invention of the photophone, by means of which sounds and articulate speech could be conveyed from one place to another by a pencil of light, he stated at the same time that the radiant vibrations of sunlight by which this result was secured were only to a moderate extent impeded by a sheet of hard rubber thick enough to shut out to the eye every trace of light even from the concentrated rays of the sun.

It had also been noticed some time ago by others that a sheet of hard rubber was not a perfect shield for a sensitive plate if there was any considerable exposure to sunlight. (See also Photography of the Infra-red region of the Solar Spectrum. W. H. Pickering, Ph. D., *Pro. Am. Acad. of Arts and Sciences*, 1864).

Moreover, Carey Lea, of Philadelphia, more than twenty-five years ago showed that a negative plate could be so acted upon as to develop an image, on applying the usual developer, by the application of very moderate heat and even of slight mechanical pressure. (See his Manual of Photography, 2d Edition, 1871, p. 408.)

This last is of special interest in connection with Tresla's recent suggestion that the Roentgen pictures may be due to the mechanical action of the impact of particles actually driven at high velocities from the cathode pole.

While the above facts detract nothing from the originality and merit of Dr. Roentgen's real discovery, they are of use in helping us to appreciate what is its important and central characteristic and to discriminate between the same and many of the so-called repetitions and extensions of his work with which the daily papers have been filled.

The Roentgen discovery differs from all that went before, not in the broad fact that some sorts of radiation would act on sensitive plates when by passing through certain screens or otherwise they had become or were invisible, but in that this investigator has shown a new sort of vibrations absolutely devoid of luminous properties and yet capable of *easily* penetrating certain materials of the greatest optical opacity, such as black paper.

The experimenters who have been producing shadow photographs with sunlight, electric lights, and the like have not been repeating Roentgen's operations, but only applying facts known for fifteen or more years.

There is another part of Roentgen's work which, though followed up by some, has as yet excited much less general attention, partly no doubt because the materials and conditions for making experiments are less easy to secure, and also because the results are not permanent, but must be inspected while they are being produced. I allude to the developments of fluorescence and the production of shadow pictures visible on a fluorescent screen.

To make this subject clear, and, as before, to bring out the exact novelty of Roentgen's work in this connection also, I must go into the early history of the subject of fluorescence.

This was first systematically studied by Professor Stokes, of Cambridge, England, and admirably developed in his classical paper in the *Philosophical Transactions* for 1852, Part 2, p. 466, *et seq.* In this place he shows that quite a number of solid bodies and solutions possess the power of absorbing light vibrations of various wave-lengths and then instantly emitting them again, but always with an increase of wave-length. Thus, for example, a solution of acid sulphate of quinine will absorb the extreme violet rays of the spectrum, and then emit them as bright blue rays. Again, an alcoholic solution of chlorophyl (the coloring matter of plants) will absorb yellow rays, as well as shorter ones, and emit red light.

There are many other bodies acting on and producing different rays, but in every case the emitted ray is of greater wave-length, or as we may say, lower in the spectrum than the absorbed or exciting ray.

As might naturally be expected on this principle, the extremely short wave-lengths of rays above the visible violet of the spectrum causes them to be absorbed by most fluorescent bodies, and emitted as rays of greater wave-length and therefore visible, and thus in this way, also, was supplied a method of making invisible light of solar vibrations visible.

In fact Stokes showed that if a solar spectrum was thrown on a block of "canary glass" (glass colored greenish yellow by oxide of uranium) its upper end was elongated or rendered visible by the fluorescent light developed, just as it was similarly extended upwards when photographed upon a sensitive plate.

Besides canary glass many other materials could be used, the most efficient being a sheet of paper coated with a paint made from finely pulverized crystals of the Platino-cyanide of barium. This subject was further investigated in this special relation by Stokes and also by Miller in 1862. (See *Phil. Trans.*, 1862.)

In 1872 the present writer had the good fortune to discover in and extract from certain dense and tarry petroleum distillates a hydrocarbon to which he gave the name Thallene, which possessed this property of fluorescence in a pre-eminent degree. Itself of a light lemon-yellow color if spread as a pigment on paper, it shines

out with a flood of grass-green light when placed in an invisible part of the spectrum or when there fell upon it violet or blue light.

Its peculiar properties were exhibited at a lecture on Fluorescence, delivered in the Academy of Music in Philadelphia in 1872, in the following manner:

A screen or curtain, about 20 feet square, of muslin of the yellow color of Thallene was prepared, and to this was attached a design of leaves, wreathes, etc. made of paper coated with Thallene. Seen by gaslight this design could not even be recognized at a short distance, but when the rays of a powerful electric light, sifted through a dark purple glass which cut off all but the violet and super-violet radiations, were thrown on it the design fairly blazed out in vivid green on a background of muslin, which looked as dark as black velvet. The yellow muslin could not reflect any of even the violet light, but the Thallene turned this, as well as the super-violet invisible rays, into green light. A full account of this material will be found, among other publications, in *The Chemical News* of London, 1872, Vol. 26, p. 272; The London and Edinburgh *Philosophical Magazine*, 1873, Vol. 45, p. 89, and the *American Chemist*, 1873, Vol. 3, pp. 81 and 162.

The general subject of "fluorescence" is also discussed at some length by the present writer in the article under this heading, in Johnson's American Encyclopædia.

Here, then, we see, that prior to Roentgen's experiments, it was well known that certain practically invisible rays could produce visible effects through the action of "fluorescence."

What Roentgen has added to this is the knowledge that such rays are developed in peculiar abundance in the highly exhausted tubes known as "Crookes Tubes," and that they will penetrate with unexpected facility a great many optically opaque substances.

Just what is the distinguishing character of these peculiarly actinic and fluorescogenic rays is at present a problem enshrouded in great obscurity, by reason of the conflicting statements of experimenters.

Roentgen and others say that they proceed from the cathode terminal. Professor Rowland and others say that they come from the anode. Tresla thinks that they are not vibrations of any sort, but are streams of projected material particles.

It would seem that the judicious course is to build no theories, but to extend experiments and accumulate facts. This is being done by various able and experienced investigators who have not been in haste to publish the incomplete results of their work. Among these we would refer to Professor O. N. Rood, of Columbia College, New York, and Professor A. M. Mayer, of the Stevens Institute of Technology, New Jersey. Among their interesting results is an absolute demonstration that the X rays are incapable of polarization.

This property was indicated by Professor Roentgen in his original publication, but not positively established, and is of great importance as radically distinguishing the new radiation from any known variety of heat, light, or actinic vibrations.

HEATING VALUE OF THE VOLATILE PORTION OF BITUMINOUS COAL.

BY WILLIAM KENT, M. E., '76.

About a year ago I received a letter from a student in the Senior Class of the Stevens Institute, stating that he was thinking of writing a thesis on analyses of the volatile matter in coals, and asking me to quote him some references to printed matter on the subject, and to give him some advice how to conduct his research. My reply gave him a few references and a brief outline of the line of work that I would suggest, but as the scheme I laid out for him involved a rather formidable amount of chemical analysis, and as his time was limited, he abandoned his project and chose for his thesis a subject which could be handled with less time and labor. The subject is perhaps too difficult a one to be treated satisfactorily in a graduating thesis, but at some future time two or three ambitious students might possibly undertake it in conjunction, each one doing a share of the work, or it might be undertaken by a post-graduate working for the Ph. D. degree. If the research could be made to include, together with the analyses of a variety of American coals of different characteristics, determinations of their total heating value, and of the heating value of their volatile portions, such as might be made by the Berthelot or Mahler calorimeter, it might be not only of great scientific value, but of great commercial importance. In the burning of the bituminous coals of the United States there is a waste which amounts to many millions of dollars annually, due to the non-combustion of a large part of the volatile matter. A thorough scientific research into the chemical constitution and the heating value of the volatile constituents of coals of different characteristics might lay the foundation for the inventions of furnaces or other apparatus by which a great portion of this waste might be avoided.

At the request of Dr. Stillman I send this article to the INDICATOR, giving some of my ideas on the subject, in the way of a suggestion to some one who may be disposed to undertake a re-

search of this kind. I will begin by quoting from the letter I wrote to the student mentioned above, with some slight amendments:

The subject you name would be an excellent one for a graduation thesis if you have sufficient time to carry out the chemical research, which its proper treatment would require. For analyses of the volatile hydrocarbons see Groves and Thorp's Chemical Technology, Vol. I., Fuels, pp. 31-34, and consult the papers therein referred to—viz., *Journal* Chem. Soc., 1885, p. 325; Foster, *Proceedings* Inst. C. E., April, 1884, and Mills on Destructive Distillation. Also consult S. T. Sadtler's Handbook of Industrial Organic Chemistry. For heating power of coal see my paper in Mineral Industry, Vol. I., 1892, p. 97, and the papers referred to therein. I know of no formula for the heating power of the volatile portion of coal except Dulong's and its modifications (see Mineral Industry, p. 100), but I would think it probable that in that formula the heating value of C should be taken at some higher figure even than Berthelot's (8,140 calories) since the C in the volatile matter is gaseous and not solid carbon, from which latter the figure 8,140 was obtained.

I would suggest a research something like the following: Obtain several samples of coals, differing widely in composition—viz., (1) soft anthracite, (2) semi-bituminous, as Cumberland, (3) Pittsburg, (4) Hocking Valley, O., (5) Illinois, high in volatile matter, (6) Lignite. Treat each as follows:

(1) Pulverize, mix thoroughly, dry at 212° Fahr., and put away for further use in glass-stoppered bottle.

(2) Make ordinary proximate analysis.

(3) Make thorough ultimate analysis for C, H, O, N, S.

(4) Subject a sample to fractional distillation, using a glass retort and a mercury thermometer for temperature of distillation from 250° to 700° Fahr., raising temperature about 100° at a time.

The residues remaining after heating to a temperature at which the glass retort would soften might be further distilled in a porcelain tube inclosed in a furnace whose temperature was measured by a LeChatelier or a Uehling and Steinbart pyrometer.

The distillates obtained at each 100° of temperature may be one or both of two classes—(1) condensable vapors, and (2) fixed gases. The former should be collected in a tube surrounded by cold water, and the latter in a jar over mercury. The separate con-

densed distillates for each 100° should be weighed and the fixed gases measured at atmospheric pressure and at standard temperature, say 62° Fahr., and then each should be separately analyzed.

Some of the problems to be solved are the following: Is the volatile matter of any sample, as determined by ordinary proximate analysis, a constant quantity, or does it depend upon the temperature of distillation and the time? Thus a certain hydrocarbon, as tar or oil, may be entirely volatile if heated for a certain time to a certain temperature, but if heated rapidly to a higher temperature it may split up into different compounds, and leave a residue of fixed C. Does the O of coal containing O in combination leave the coal as O, or as H_2O, and at what temperature does it leave? Does the distillation at low temperature remove valuable fuel elements chiefly, hydrocarbons high in H, or H_2O? Does the character of the distillates at different temperatures differ in different coals, and if so, in what respect?

From a study of Mahler's calorimetric investigations (Mineral Industry, Vol. I., p. 97), the Mechanical Engineer's Pocket Book, p. 634.), I constructed the following table of the approximate heating values of coals of different analyses:

APPROXIMATE HEATING VALUE OF COALS.

Percentage of Fixed Carbon in Coal Dry and Free from Ash.	Heating Value. B. T. U. per Lb. Combustible.	Equiv. Water Evaporated from and at 212° per Lb. Combustible. Lbs.
100	14,500	15.00
97	14,760	15.28
94	15,120	15.65
90	15,480	16.03
87	15,660	16.21
80	15,840	16.40
72	15,660	16.21
68	15,480	16.03
63	15,120	15.65
60	14,580	15.09
57	14,040	14.53
54	13,320	13.79
51	12,600	13.04
50	12,240	12.67

One of the objects of the proposed research might be to determine how far the above figures (which were made from Mahler's tests of European coals) hold good for American coals.

From a study of results of a great number of boiler tests with American coals, I made the following table of the probable maximum boiler test results obtainable from coals of different fixed carbon percentages (fixed carbon in total combustible):

Fixed Carbon, Percentage.					
97	80	68	60	54	50
Evaporation from and at 212° per lb. combustible, maximum.					
12.2	12.5	11	10	8.3	7.0
Boiler Efficiency, Percentage.					
80	76	69	66	60	55
Loss, chimney, radiation, imperfect combustion, etc.					
20	24	31	34	40	45

The difference between the loss of 20 per cent. with anthracite, fixed carbon ratio 97 per cent., and the greater losses with the other coals is chiefly due to imperfect combustion of the bituminous coals, the more highly volatile coals sending up the chimney the greater quantity of smoke and unburned hydrocarbon gases.

Two questions upon which the proposed research may throw some light are: (1) What is the character of the volatile matter of the more highly bituminous coals; and (2) may it not be commercially practicable to get rid of the least valuable portion of this volatile matter, by some kind of coking process, at the coal mines, and save freight not only upon it, but also on so much of the fixed carbon which is wasted in the ordinary boiler furnace in the operation of distilling the volatile matter? If any of the Western coals containing high percentages of oxygen contain it in such chemical combination that it can be removed at a comparatively low temperature at the coal mine, it would appear that a partial coking of these coals at the mine would be commercially practicable. Even if the oxygen cannot be removed except at a high temperature, it may be found that it carries with it in distillation the valuable by-products which are obtained in the Otto–Hoffman and the Semet–Solvay coking processes, and that their extensive introduction in

the West would pay. There is a possibility of fractional distillation of Western coals giving three valuable products, first, gas approximating in composition to natural gas or methane, CH_4, which could be utilized in factories within a certain distance; second, ammoniacal tar waters, containing valuable substances for use as fertilizers or in the chemical industries; third, smokeless coal or coke, which would be the final solution of the smoke problem in the Western cities.

As an example of the widely different results that may be obtained in boiler tests with different coals I will give some results with two coals I tested recently in Ohio with the same boiler and the same method of firing—viz., with the American underfeed stoker. With Jackson County, Ohio, coal the result obtained was 8,577 pounds of water evaporated from and at 212° per pound of combustible. With New River, W. Va., coal the result was 12,252 pounds.

The proximate analysis of the coal was as follows:

	Ohio Coal.		West Virginia Coal.	
	Coal.	Dry Combustible.	Coal.	Dry Combustible.
Moisture, percentage,	3.83	....	1.18	....
Volatile matter,	32.07	35.76	20.92	22.24
Fixed carbon,	57.60	64.24	72.90	77.76
Ash,	6.50	....	5.00	....
	100.00	100.00	100.00	100.00
Heating value, by Carpenter calorimeter, B. T. U.,	13,170	14,620	15,350	16,210
Boiler efficiency,	....	56.65	....	72.99

The heating value of the West Virginia coal is remarkably high, being over 2 per cent. higher than the highest figure in the table of approximate heating value of coals, given above. The heating value of the Ohio coal is over 3 per cent. less than the figure for coal of 63 per cent. fixed carbon ratio given in the same table.

An interesting computation of the heating value of the volatile portion of the combustible of each of these coals may be made as follows: Taking the heating value of pure carbon at Favre and

Silbermann's figures, 14,544 B. T. U. per pound, the 77.76 per cent. of fixed carbon in the West Virginia coal would give 11,309 B. T. U.

Take this from the total, 16,210

gives 4,901

Dividing this by 23,616, Thomson's figure for the value of marsh gas, or methane, CH_4, gives 20.75 per cent.; that is, the 22.24 per cent. of volatile matter in the coal was equivalent to 20.75 per cent. of methane, or the volatile matter in this coal was 93.3 per cent. of the value of methane.

For the Ohio coal 64.24 per cent. × 14544 = 9343 B. T. U.

Take this from the total, 14620

gives 5277

which, divided by 23,616, gives 22.34 per cent.; that is, the 35.76 per cent. of volatile matter in the coal was equivalent to 22.34 per cent. of methane; plus 13.42 of volatile matter of no value, or the volatile matter was only 65 per cent. of the value of methane.

Another interesting study which may be made in connection with the subject, is that of a comparison of coal calorimeters Scheurer-Kestner and Meunier-Dollfus, published as one of the conclusions made from their tests in 1868 (see Mineral Industry, Vol. I.), the statement that the heating power of coal generally was greater than that calculated by Dulong's formula from its ultimate analysis, the excess averaging about 10 per cent. Mahler's results show a remarkable agreement of the calorimetric results with analysis, the average of the former being less than 0.4 per cent. of the latter, while Mr. F. W. Dean, of Boston, at the recent meeting of the American Society of Mechanical Engineers, presented a series of results made with the Thomson calorimeter which showed that the calorimetric results were only from 93 to 97 per cent. of the calculated results. Whether these discrepancies were due to errors in calorimetry or to different characters of the coals is a matter which should receive investigation.

REVIEW OF THE PRESENT STATUS OF IRON ANALYSES.*

BY GUS. C. HENNING, M. E., '76.

Every comparison must be based on a fundamental principle or groundwork, and therefore it becomes necessary for me to state at once whereon I shall base my argument. If the foundation is insufficient, the superstructure is sure to fail; there may be other reasons, supplementary or external, which may cause defects or collapse, but these are only secondary and can be controlled. The basis of my argument shall be this:

"*A correct chemical analysis is equivalent to a complete identification of any substance.*" The positive identification of substances by their chemical analyses is in fact the aim and end of analytical chemistry, and the sole reason for making analyses of products of commercial or technical processes. It has always been claimed that a knowledge of constituent elements is synonymous with a knowledge of the compound itself.

In organic compounds the work is of such a difficult and delicate nature, and the constituent molecules are often of such a fragile character, that the highest skill is necessary to arrive at results, and the identification of substances is rather by interpolation and comparison than by positive knowledge of measurements. In the case of metals, metalloids, or non-metals—that is, in inorganic substances, chemical science is so far advanced that, as a rule, analyses may be made with mathematical accuracy.

When C enters into combination with metals, however, difficulties seem to arise which are unique, and the component elements do not appear to have simple relations, but form molecules, which in many cases are similar to organic compounds, changeable by heat or pressure, losing or changing their identity, as the case may be,

*Lecture delivered before the American Chemical Society, New York, January 10, 1896.

and sometimes being reconvertible. The molecules being of various kinds, have distinct properties which, under certain conditions, can be readily identified. The combinations of the metal with C are not of a simple character, but take place in a complex manner. That is, the two elements do not unite in one compound of fixed chemical composition or proportion, but a number of various chemical compounds of distinct different properties and atomicities are found, and these unite among themselves to form the complete substance and determine its properties. It may not be possible to separate these distinct chemical compounds, because immediately they are removed from their surrounding affinities they seem to lose their identity.

This seems to be particularly true of the element Fe with C and because cast iron, steel, and wrought iron contain but 10 per cent., or less, of C and other elements, and 90 per cent. of Fe, therefore I will refer throughout my remarks to "iron" as the name of a class of materials, instead of the usual much misused terms previously given, which always lead to confusion and misunderstanding.

Comparison of results of analyses of iron made by the most prominent metallurgical chemists in this country and abroad, shows that sufficient knowledge to make correct iron analyses is lacking. That ready methods used in routine work should be more or less inaccurate can be overlooked, but when 23 metallurgical chemists of repute, each knowing that analyses of the same material were to be made by other chemists for purposes of comparison, cannot obtain results within 7 per cent. either way from the average of all the results, we have a right to question the skill of the chemists.

This statement is based upon results of P determinations as given in a paper compiled by George E. Thackray, Assistant Engineer of the Cambria Iron Company, Johnstown, Pa., presented at the October meeting of the A. Inst. M. E., 1895.

From this paper I quote as follows: "But as considerable discussion had taken place regarding the accuracy of various methods for phosphorus determination, in the hands of different operators and under different conditions, it was decided to enlist the co-operation of various chemists throughout the country, in the hope of throwing some light on this vexed question. For this purpose about forty samples were prepared from each of two open-hearth steel billets, each 5 inches long and 2½ inches square, numbered

19,915 and 19,533 in the tables below. The regular analyses of these two heats made at the works' laboratory were as follows:

"TABLE I.—*Ordinary Complete Analyses of Samples Distributed for Phosphorus Determinations.*

	No. 19,915.	No. 19,533.
	Per Cent.	Per Cent.
Silicon	.060	.061
Sulphur	.048	.043
Phosphorus	.047	.082
Manganese	.660	.480
Carbon	.410	.280
Arsenic	Slight traces.	

"Before sending out these samples, the drillings were taken carefully from all parts of the billet, thoroughly mixed and carefully divided. The samples were sent to a number of steel works, and to various commercial chemists, with a letter of transmittal advising all that samples had been sent elsewhere, and that tabulated results would be forwarded to each participant when completed."

The results of these analyses are given in Table II., and bear out the previous statements when taking individual analyses; when comparing variations between mean results and general averages we find in first case 4 per cent. over and 3.9 per cent. under; and in second case 4.1 per cent. over and 3.16 per cent. under.

After describing the 26 methods used by the various chemists, the author draws one conclusion from this otherwise very valuable paper—viz.: "It is hoped that the showing made herein with respect to phosphorus determinations will be of some value; and that it should carry considerable weight as evidence of the general accuracy of such work, and may be considered good testimony as against the pessimistic opinions so often encountered in discussions of this subject."

In this conclusion I most thoroughly disagree with the writer, because I cannot admit, that, differences of 4 per cent. ± between a general average and the mean results from which it is derived, show "the general accuracy of" P determinations. Determinations of Si, S, Mn, and Cu do not give so much trouble, and nothing need be said about them. Ti, As, Cr, Mo, V, W, and Al may also be neglected, because they are found in quantity in special irons

TABLE II.—*Comparative Statement of Results Obtained by Different Chemists on Drillings Taken from the Same Piece of Steel (2.5 inches square and 5 inches long) and Thoroughly Mixed Before Division for Distribution.*

	Results of Phosphorus Determinations.						Differences Between Means and Averages.	
	Sample No. 19,915.			Sample No. 19,533.				
	Method.	Per Cent. Details. I.	Per Cent. Average. II.	Method.	Per Cent Details. I.	Per Cent Average. II.		
Andrew A. Blair, Booth, Garret & Blair, Philadelphia, Pa	A.	.049		A.	.080			
	A'.	.051	.050	A'.	.084	.082	+.0003	—.0012
Millard Hunsicker, Engineer of Tests, J. M. Camp, Chemist, Duquesne, Pa., Carnegie Steel Co, Pittsburg, Pa.	B.	.052	.052	B.	.085	.085	+.0023	+.0018
Hugo Carlsson, The Johnson Co., Lorain, O	C.	.050	.050	C.	.080	.080	+.0003	—.0032
Townsend V. Church, Chief Chemist, F. Julian, Chemist, Illinois Steel Co, South Chicago, Ill	D.	.052*	.052*	D.	.088	.088	+.0023	+.0048
Albert Ladd Colby, Bethlehem Iron Co., Bethlehem, Pa.	E.	.045	.045	E.	.080	.080	—.0047	—.0032
Benedict Crowell, Otis Steel Co., Cleveland, O	F.	.053	.053	F.	.086	.086	+.0033	+.0028
Dr. C. B. Dudley, Pennsylvania Railroad Co., Altoona, Pa.	G.	.054		G.	.091			
	G.	.054	.054	G.	.090	.0905	+.0043	+.0073
Dr. T. M. Drown, Boston, Mass	H.	.049	.049	H.	.084	.084	—.0007	+.0008
Frank E. Hall, Union Rolling Mill Co., Cleveland, O	I.	.053		I.	.085			
				I.	.087		+.0033	+.0023
	J.	.055	.054	J.	.081			
				J.	.089	.0855		
Dr. P. L. Hobbs, Cleveland, O.	K.	.046	.046	K.	.080	.080	—.0037	—.0032
Fred. D. Jones, Youngstown Steel Co., Youngstown, O.	L.	.052		L.	.086			
	L.	.052	.052	L.	.086	.086	+.0023	+.0028
S. W. McKeown, Youngstown, Ohio	M.	.049	.049	M.	.084		—.0007	
				M.	.085	.0845		+.0013
R. B McKeown, Andrews & Hitchcock, Hubbard, O	O.	.049		O.	.082			
	O.	.050		O.	.084			
	M.	.050	.04966	M.	.084	.08333	—.00004	+.00018
W. W. McKeown, Cherry Valley Iron Works, Leetonia, O	P.	.049		P.	.083			—.0002
	Q.	.049		Q.	.083	.083		
	G.	.050	.04933				—.00037	
A. S. McCreath, Harrisburg, Pa	N.	.049	.049	N.	.081	.081	—.0007	—.0022
W. J. Rattle, Cleveland, O.	R.	.051	.051	R.	.083	.083	+.0017	—.0002
Dr. M. E. Rothberg, Cambria Iron Co., Johnstown, Pa.	S.	.045		S.	.081			
	S.	.046		S.	.082			
	S.	.046		S.	.082			
	T.	.046		T.	.078			
	U.	.046	.0458	U.	.076	.0798	—.0039	—.0034
Porter W. Shimer, Easton, Pa.	V.	.047	.047	V.	.081	.081	—.0027	—.0022
Frank G. Slocum, Jones & Laughlin, Pittsburg, Pa.	W.	.047	.047	W.	.080	.080	—.0027	—.0032
Oscar Textor, Cleveland, O.	X.	.048	.048	X.	.079	.079	—.0017	—.0042
George P. Vanier, Pennsylvania Steel Co., Steelton, Pa	Y.	.048	.048	Y.	.078	.078	—.0017	—.0052
Fred. H. Williams, Riverside Iron Works, Wheeling, W. Va.	Z.	.050		Z.	.090			
	Z	.051	.0505	Z.	.089	.0895	+.0008	+.0063
, Pittsburg, Pa.	B.'	.051	.051	B'.	.085	.085	+.0013	+.0018
e		.04966	.0497		.0835	.0832		

only, but are of greatest importance. Iron analyses are generally so incomplete, being rarely made for more than C, P, Mn, S, Si, Cu, and As, that it is easily possible that one or more of the rare elements may be present and cause peculiar properties, without being detected; Ti and W are remarkable in this respect, and their determination should not be overlooked.

One of the elements in iron analyses, which is generally not determined, is Fe; if it is given at all, it is usually stated "by difference."

I think you will agree with me that this is not a scientific method, to say the least; there can be little question that this has often been the cause of overlooking other important admixtures, just as it has been for long periods of time the cause of failure to identify unknown elements, which lay concealed in what chemists called "slight residues," or similar indefinite substances. The latest instance of this kind was the failure to identify "argon" in atmospheric nitrogen.

As a basis for my next remarks I take the following papers: "Unification of Methods of Iron Analyses," by Prof. Dr. H. Wedding, of Berlin; "Unification of Methods of Iron Analyses," by Baron H. Jueptner von Jonstorff, of Neuberg, Austria, both read at the Zurich Conference on Testing Materials. Baron von Jueptner, in his valuable paper, quotes the analyses published by J. W. Langley in the *Journal Am. Chem. Soc.*, 1893, p. 448. These analyses were made by three expert committees, one English, one Swedish, and one American, and using five standard samples, in each of which C, Si, S, P and M were determined. There can be no doubt that these results are the very best obtainable under most favorable conditions, but still they vary many per cent., and while they are negligible for many technical purposes, they are still so large that they would be very misleading in practice.

These discrepancies may be due to:

1. Errors of instruments used.
2. Errors of analytical methods.
3. Errors of manipulation.
4. Personal equations of chemist.
5. Errors in atomic weights, used as bases of calculation.
6. Irregularities in material analyzed.
1. The first need not be discussed, being well known.

2. *Errors due to methods*, are one of the most important sources of discrepancies. Among these are, incomplete oxidation of C in chromic and sulphuric acid methods; neglect of various forms of C in Eggertz' method; loss of S, in all determinations depending upon solution of H_2S, leaving a residue of insoluble S; the ready decomposition of the permanganate and several others, which cannot be referred to now.

3. *Errors of manipulation*, depending upon unavoidable losses, and those accretions depending upon destruction of glass and porcelain dishes, and variation in per cent. of ash in filter papers, etc.

4. *Personal equations of chemist*, are no doubt important, but the study of which is very difficult; the only method of eliminating them would be by making many repeated analyses by many chemists under exactly identical conditions, similar to astronomical work.

5. *Atomicity of elements.* Even the latest determination of these are in some respects so far different that in Fe, for instance, they produce differences of 1½ per cent. in results! Atomic weight of Fe and Mn as determined by

	Fe.	Mn.
F. W. Clark	55.913	53.906
L. Meyer and K. Seubert	55.88	54.8
Van der Plaats	56.0	55.0

These figures when used in the chlorate method with oxalic acid and an 80 per cent. ferromanganese would give, according to

	Mn.
F. W. Clark	80.000 per cent.
Meyer and K. Seubert	81 353 "
Van der Plaats	81.484 "

or as above, differences of 1½ per cent.!

This circumstance confronts us with the alternative of either establishing standard atomic weights, or to redetermine them.

6. *Irregularities in material analyzed.* This leads to such errors, on account of separation of substances of widely varying Sp. Gr. of particles in a finely divided state that the author proposes discarding drillings or powder, and use small pieces for analyses, the whole of which are dissolved. The author then asks: "What *demands* are to be made upon analysis?" He considers that for general supervision of processes or works, relative accuracy suffices. But for commercial purposes, analyses can only be satisfactory when methods

are agreed upon in advance, but this makes the accuracy again only relative.

However, when analyses should serve to give information about peculiar behavior of any iron, it becomes a vastly different matter. In this case, as well as for scientific purposes, and in all those where the chemical analysis is to serve the purpose of determining the relation between composition and physical properties, absolute accuracy becomes of primary importance. Healer points out that irons are by no means homogeneous in their composition like minerals, but that they rather resemble "rocks," being an aggregation of various compounds, and there can be no question that several irons of identical elementary composition may possess totally different physical properties, according to the grouping of the various elements composing them.

Now let us take up Dr. Wedding's paper. He points out that, although the physical and mechanical properties of iron depend primarily upon the elementary chemical composition, they are largely controlled in a variable measure by the manner of distribution of the elements and their compounds among the structural units, and by the arrangement which the latter assume. The distribution of chemical constituents among the crystallographic arrangement, which could heretofore be determined by the use of the microscope alone, depends upon the method of cooling the iron after its production, and usually upon the rate of cooling from the liquid state, assuming that its elementary composition is the same. This crystallographic structure, although being dependent upon rate of cooling, is also largely affected by mechanical work, such as compression and impact produced by hammering, rolling, and pressing (hydraulic forging). Assuming that these were identical during the production of two pieces of iron, then the physical-mechanical properties would be controlled by chemical composition. Dr. Wedding also points out that the H and O methods of analyses must depend upon composition, because the same methods with different compositions by no means give equal accuracy of results.

He also refers to difficulties in Si determinations in the presence of SiO_2 (silicic acid), as the two can co-exist without that the latter takes up O to form slag. Speaking of analyses of the various modifications of C, the following statement is made: "It should be recalled that the knowledge of the great effect of different modifi-

cations of C in iron upon its mechanical and physical properties has led to the attempt at analytical separation into graphite and temper carbon, as well as carbide and hardening carbon, although as yet, with hardly even approximate accuracy."

Very little has yet been done in the directions of H and O determinations, because, until recently their constant presence in all forms of iron was not generally recognized and their important influence on quality was even denied. That O in the shape of Fe_2O_3, has long been known to be a very undesirable admixture, but its quantitative determination has been very difficult and has not yet been developed with satisfactory accuracy. As is well known, Fe, especially in sections, becomes quite brittle upon absorbing H in the nascent state at ordinary temperatures, but reheating again drives it off. Long periods of quiescence in the absence of free H produces the same result. As iron is generally tested immediately after manufacture, the presence or absence of H should be determined. There is one other element, however, to which I must give considerable space, because it or its combinations are the all-important and controlling admixtures in irons. This is C and its various chemical combinations with Fe, rather than that which is free or uncombined.

The three papers named below shall serve as basis for my review of this element; they are:

On "Microphotography of Iron," by F. Osmond, of Paris; on "Microphotography of Iron," by A. Martens, of Berlin; "On the Influence of C on Fe," by Prof. John Oliver Arnold, F. C. S, of Birmingham, England.

Microscopical examinations of iron, first made by Dr. Sorby in 1865, have led to remarkable developments of our knowledge of structure and of the constituent elements. Professor Ledebur and Dr. Mueller separated some of the latter many years ago, but not all, and only recent investigations by Osmond, Martens, Arnold, and a few others have shown what a vast field lies undiscovered before us and what a valuable adjunct to analytical chemistry the microscope has become. As you may wish to study this subject further, I would call your attention to the valuable bibliographies on this subject by F. Osmond in *Journal I. and S. Inst.*, 890, No. 1, a second by the French Commission on Testing Materials, Ministère des Travaux Publics, Paris, 1892 and 1805, and a third by

R. A. Hadfield, *Journal I. and S. Inst.*, 1894, No. 1. These microscopical examinations have shown that structure of iron depends upon a number of partially identified compounds which have been given the names of Pearlit, Cementit, Martensit, etc., etc., and which are all compounds of C and Fe.

Marten's and Osmond's latest investigations, as well as those of Arnold, have demonstrated that the presence or absence of one or more of these compounds determines and identifies the qualities and properties of different kinds of iron and also determines the methods of manufacture and heat treatment to which they were subjected.

Messrs. Abel, Mueller, and Ledebur showed some years ago that carbon in unhardened steel exists chiefly as the definite carbide Fe_3C; but microscopical investigations have further proven the coexistence of many other carbides, especially after heat treatment. Professor Arnold claims to have proven the existence of:

(*a*) Crystals of pure iron which remain bright upon etching;

(*b*) Crystals of slightly impure iron which become pale brown on etching, probably owing to the presence of a small quantity of an intermediate carbide of hypothetical formula $Fe_{10}C$;

(*c*) Normal carbide of iron Fe_3C, which exists in three distinct modifications; each one conferring upon the iron in which it is found particular mechanical properties.

(1) Emulsified carbide present in an excessively fine state of division in tempered steels.

(2) Diffused carbide of iron occurring in normal irons in the forms of small ill-defined striæ and granules.

(3) Crystallized Fe_3C occurring as well-defined laminæ in annealed and in some normal irons.

(*d*) Subcarbide of iron, a compound of great hardness existing in hardened and tempered irons and possessing formula $Fe_{24}C$. This substance is decomposed by the most dilute acids, and at 400° C. it is decomposed into Fe_3C and free iron with evolution of heat. One of the most remarkable properties of this compound is its capacity for permanent magnetism.

(*e*) Graphite or temper carbon.

Chemists have heretofore identified only graphite carbon, combined carbon, and carbide of iron. These alone are not sufficient to identify iron, and what must be done is to devise accurate

methods for determining all of the above-enumerated substances by chemical analysis; not until then can chemists claim to be able to make analyses which are either complete. critical of definitive in regard to C.

Professor Arnold says: "The existence of $Fe_{24}C$ is proved by the fact that iron containing 0.89 per cent. C presents several correlative critical points when examined by different methods of observation: (1) Well-marked saturation points in micro-structure of normal annealed and hardened steels. (2) A sharp maximum in a curve, the co-ordinates of which are heat evolved or absorbed at Ar 1 (point of recalescence) and C percentage. (3) A point in the compression curve of hardened steels at which molecular flow absolutely ceases. (4) A sharp maximum in a curve, the co-ordinates of which are C percentage and permanent magnetism in hardened steels.

Now, it seems to me, that compounds which have such great influence on properties of substances should be determined by chemical analyses with exactness instead of giving merely the totals of the elements contained.

We now come to the work of the famous French micrographist F. Osmond, who defines and describes five distinct substances which can always be found and identified by the microscope, as existing in iron subjected to heat treatment; these are always, I wish you to bear in mind, carbon compounds.

(1) The first he calls, with Howe, Ferrit, because it is almost pure iron; it at first retains a dull polish (poli spéculaire) when relief polished; after continued polishing, especially with precipitated chalk and water, it becomes more granular as it is less massive, but when forming large vessels it finally shows as polyhedral crystals. Etch polishing with tincture of iodine produces no coloration.

(2) The second is called Cementit, which is distinguished by its hardness (felspar, No. 6, Mohr's scale). This hardness, which is greater than that of all other C compounds, permits its identification even when polishing with emery paper, provided it is not so bedded in softer particles, that the microscope is no longer able to identify it, and chemical analysis alone is able to prove its presencc. This substance corresponds to that imagined by Karsten and Caron, and isolated by Dr. F. C. G. Mueller, Sir Fred. Abel, and Professor

Ledebur as carbide, and of the probable formula Fe_3C, and which Howe also calls Cementit. Osmond believes that cementit of iron of cementation (de l'acier poule) can now be identified with the hard component of cast and forged steels.

(3) The third compound is called Sorbit, after Dr. Sorby, which was first described as "pearly constituent" (Howe called it Perlit), which could be identified under a magnification of 800 diameters, as a substance with the sheen of mother-of-pearl. It is possible, with oblique light, to separate this in bands of alternating hard and soft flakes.

Osmond questions the accuracy of the conclusion generally held that this is Fe_3C, because he points out that etch polishing gradually changes the color from yellow to brown and then from purple to blue, and at a certain period there is great difference between the colors in adjacent "islets" (ilots).

The uncolored flakes (lamelles) may appear elevated or depressed. With tincture of iodine similar results are obtained. It must be remembered that neither Ferrit nor Cementit takes such colors under similar conditions even when extract of liquorice root or tincture of iodine is used.

He can offer no suggestions in regard to chemical compounds of "Sorbit."

(4) A fourth compound always found after quenching iron, which is already well known, is "Martensit," named after my friend Prof. A. Martens, the famous micrographer of Berlin.

When iron with 0.45 per cent. C is heated to 825° C., and then at 720° C. quenched in a freezing mixture of 20° C., relief polishing produces no effect; but etch polishing shows the structure. Groups of needles (fascicles) or groups of rectilinear, parallel fibers, which are separated or not by a scarry or vermiform filling, are shown in very slight depths. Three groups of fibers, parallel to the sides of a triangle, are often seen in one spot, as crystalline bodies of the cubical system. Etch polishing does not always color Martensit, and then only takes a light yellow sheen. However, when applying tincture of iodine it takes a yellow, brown, or black color, according to the percentage of C present. Because of the non-uniformity of color it is not quite certain whether Martensit can be considered a fundamental compound. It does, however, retain its forms even in the quenched parts, in the softest as well as in the hardest iron,

with the single difference that the fascicles (needles) are sometimes longer, sometimes more varied, in accordance whether the iron is more or less carbonized. The shapes are characteristic and permit determination of differences in hardness. Martensit is not positively a definite compound of Fe and C; it represents rather the crystalline arrangement of an allotropic modification of iron under the effect of C.

(5) A fifth well-defined fundamental compound found in medium iron quenched while undergoing structural changes (into its allotropic modifications according to Osmond) is named Troostit, after the famous French metallurgist Troost. When iron with 0.45 per cent. C. is heated to 825° C. and then quenched at 690° C., is relief polished, nodules in relief, depressed tatters or tongues (lambeaux), and between the two, intercalations of varying breadth and medium hardness are developed. Etch polishing proves that the hard nodules are Martensit, and the soft tatters or tongues are Ferrit. The intercalated bands show temper colorations, but they harden less rapidly than Sorbit under identical conditions, and these colors produce irregular marbleized appearance; they are almost amorphous, slightly granular and warty. Tincture of iodine in first and second application produces quite similar effects in this fifth fundamental compound, Troostit.

It is noticed that it is a transitory form between soft iron and hardened steel. But Troostit is identified by the microscope alone, just like the Sorbit; its composite character is still to be determined. The systematic microscopic examination consists briefly in the application of three methods:

(1) Relief polishing, (2) etch polishing, and (3) etching with tincture of iodine.

In relief polishing it is sometimes advisable to use precipitated chalk as well as rouge, to preserve the Ferrit.

In etch polishing with precipitated chalk, the fundamental compounds, with the exception of Martensit, are divided into two groups.

(*a*) Not colored: Ferrit, Cementit, or Martensit.

(*b*) Colored: Martensit, Troostit, or Sorbit.

Martensit takes only a yellowish color and is distinguishable by its crystalline form. A novice might take Martensit for Perlit, especially by oblique light, for both have iridescent sheen, and its

structural elements may be of equal dimensions; but they are easily distinguished, as the needles of Martensit are straight and crossed, while those of Perlit are curved and never cross each other.

Ferrit and Cementit differ by their great differences in hardness; the former is low, the latter high. Troostit takes less color and more slowly than Sorbit, but the true distinctive mark is that Troostit accompanies Martensit, while Sorbit goes with Cementit in Perlit.

By etching with tincture of iodine two groups can be distinguished—viz.:

(*a*) Uncolored: Ferrit and Cementit.

(*b*) Colored: Sorbit, Troostit, and Martensit.

In group (*b*) the three compounds vary in color in kind and depth in proportion to the percentage of C and of the quantity of tincture of iodine used.

I think that you will now appreciate the intensely interesting and valuable work which the micrographers have done, although I could lay before you an almost endless array of tangible proofs had I the time of preparation for such work. You no doubt appreciate from the details above given that each of these fundamental compounds have been most fully and accurately identified. I have given them in such detail because it will at once show you that a vast field has been thrown open for the most interesting and valuable, but also difficult, investigations by the chemists.

If chemistry is not able to identify all of these compounds in quality *and* quantity as fully as the microscope has done, I am afraid it will be compelled to take second place in future in iron analyses, except for preliminary work. I have not pointed out that the micrographers by their examinations determine physical and mechanical properties, because it will be self-evident to most of you that they can do this as a matter of course.

To him who will develop methods of determining these fundamental compounds by chemical means with exactness there will come fame greater than that which has fallen to any discoverer of new elements.

The chemist cannot claim to be able to identify iron, unless he succeeds in identifying absolutely all of its fundamental components. The time has passed when but three irons were known—viz., cast

and we have two and steel each made by a different method, which from one another, and which could be easily identified by chemical analyses. The art of iron making has advanced so rapidly that chemical science has not been able to keep pace with it, and many persons as applied to iron it had assumed a routine character that was formerly considered great accuracy is now so [illegible] merely.

From all the facts laid before you, I think you will agree with me that I am justified in asserting that there is still a vast amount to be done by chemists in iron analyses, both in accuracy and in [illegible].

If I could induce but one of my hearers to devote his energies to a more complete perfection of iron analyses I should consider my labors more than amply repaid, and will not feel qualms of conscience should any of you call me an inveterate sceptic.

PRACTICAL PHOTOMETRY.

BY ALTEN S. MILLER, M. E., '88.

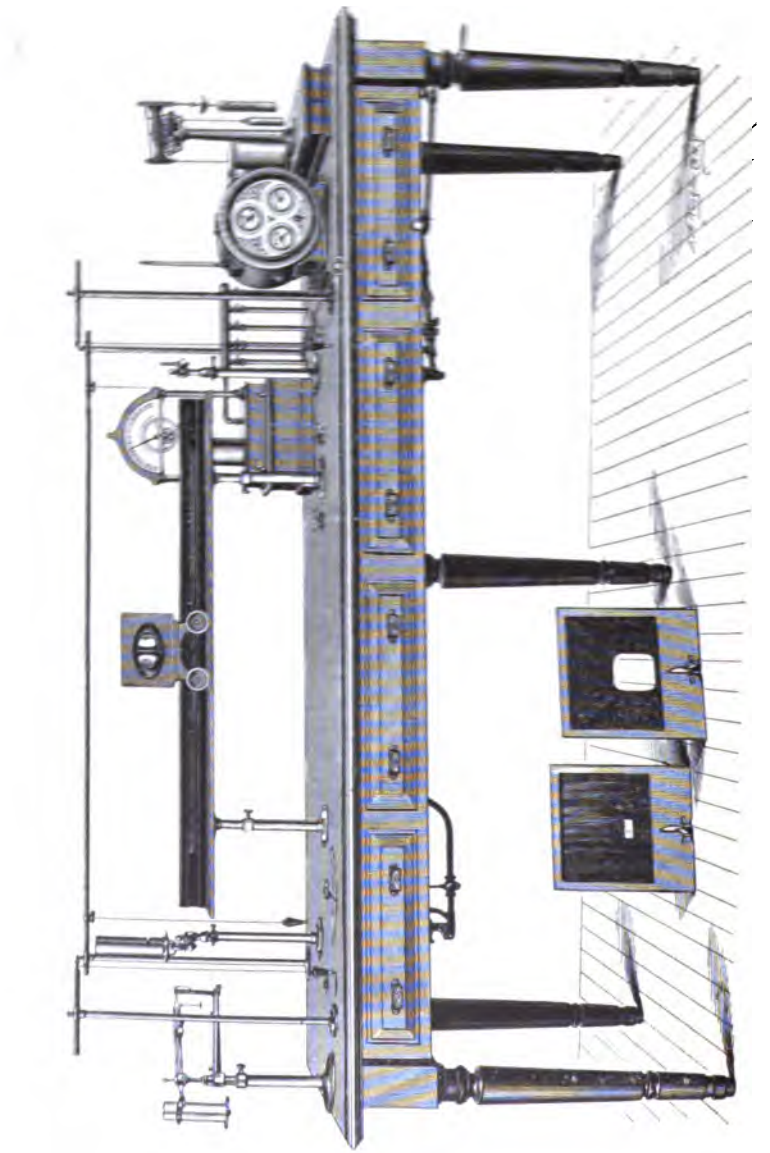
The illuminating value of any source of light is determined by comparing it with some source of light of known value. The illuminating value of gas is measured by comparing a flame that is burning at the rate of 5 cubic feet an hour with a standard sperm candle that is burning at the rate of 120 grains an hour.

The amount of light received by any object will vary inversely as the square of the distance of that object from the source of illumination, hence, if the light whose power is to be determined illuminates a body at X inches to the same degree that a standard candle would illuminate that same body at Y inches, the illuminating power of that light will be $\frac{X^2}{Y^2}$ candles.

In constructing a photometer this single principle is kept in view, and all the refinements are to eliminate errors in judgment and to allow for the variations in the rate of combustion of gas and sperm.

The accompanying illustration shows the form of photometer known as the Bunsen, which is the one most commonly used in Germany, England, and America.

It consists first of a table which carries the apparatus and on which the distance between the lights is accurately laid off and marked by two lines. This distance is generally 60 inches, but 2 meters and 100 inches are also used. In case either light is changed or moved for any reason, it may easily be put back in place by placing it centrally over the line indicated on the table. To facilitate the adjustment two plumb bobs are hung over each of the lines at the ends of the table, so it is easy to see whether the flames are properly centered in one direction. In the other direction they are centered by sighting along the bar. The bar is placed at right angles to the two lines laid out on the table and centrally between them. It is laid out in inverse squares so that "1" is in the center. If the length of the bar is Y, and the distance from the candle is X, the candle-power is $\frac{(Y-X)^2}{X^2}$. The mark that indicates four candle-power is twice as far from the



light to be measured as it is from the candle, 9 is three times as far, etc.

The bar should be made so that it may be raised or lowered at pleasure, and be planed to a thin edge on top so that no light will be reflected from it on the disk. On the bar is a sight-box in which a paper disk is placed at right angles to and centrally over the bar. There are several kinds of disks used, but the one most commonly preferred in this country is made by taking a piece of white sized paper of medium thickness, and cutting out of the center a many-pointed star about an inch and a half in diameter outside the points. This paper with the star cut from the center is then placed between two pieces of tissue paper and the three held together either by placing between pieces of glass or else by being fastened with thin starch water. At the back of the sight-box are two mirrors, so placed that the observer may stand in front of the bar and see both sides of the disk. On the front of the sight-box a hood is so placed as to partially screen the eyes of the observer from the lights.

At one end of the bar is the light to be tested. This is connected to a pipe sealed in mercury, so that it may be moved back and forth or raised and lowered at pleasure. It is usually arranged with a micrometer cock so that the rate of flow may be regulated as closely as may be necessary.

At the other end of the bar is a candle balance. The balance is usually arranged for two candles and all readings are multiplied by 2. This balance is so constructed that the position of the candles may be adjusted vertically or horizontally.

This end of the bar is so arranged that the candle balance may be removed and a standard burner put in its place. The standard burner commonly used is a Sugg Argand burner size D. This is covered with a thin sheet metal chimney 1⅞ inches diameter. This chimney has an opening on one side $\frac{13}{32}$ inch high and 1½ inches wide. On the opposite side the chimney is cut away to prevent light being reflected through the slot in front. The standard burner, like the one through which the gas is tested, is so arranged that it may be adjusted in all directions.

A meter to measure the gas is necessary. As gas is burned at the rate of 5 feet an hour when being tested, the meter is so geared that one of the hands makes a complete revolution each time a

twelfth of a foot of gas passes. A clock is attached to the meter with a large second hand, so when the meter hand mentioned and the second hand move together, gas is passing at the rate of 5 feet an hour. In addition to these hands are one indicating feet and one minutes. Some meters are furnished with a third set of hands reading feet and hundreds.

The meter has a thermometer to show the temperature of the gas and a universal level so that it may be properly leveled. On the side is a glass gauge and a mark indicating the height of the water, which should always be constant.

The pipe connections to the meter are so arranged that opening a cock will allow the gas to pass around instead of through it. This permits the operator to start or stop the meter at pleasure without interfering with the light.

A pressure gauge connected to the various parts of the apparatus enables the operator to ascertain the pressure of the gas at different points. One of these connections is to the pipe a short distance below the test burner. This gives the pressure near the point of ignition. The pressure is read in inches and fractions of an inch of water.

A gas-governor is connected before the inlet to the meter, which reduces the pressure to about an inch and a half of water. Beyond the meter is a smaller governor which reduces the pressure to about nine-tenths of an inch and prevents alteration of the flow of gas due to irregularities in the meter.

Black screens are arranged to screen the eye of the observer from the light. These are sometimes fixed and at others set on the bar. The latter arrangement is preferable, as they may be moved to suit different positions of the sight-box.

For testing gas of not over 18 candle-power the Standard London Argand burner is used. For higher candle-power gas the ordinary sawed lava tip is best. The latter is commonly known as the batwing burner.

The photometer should be set up in a small, light proof room with dead black walls. The latter can be hung with black velvet or painted with glue and lampblack. Great care should be taken to insure proper ventilation without draft. The temperature of the room should be kept as near 60° Fahr. as possible, and the air should not be allowed to become vitiated by the products of com-

bustion. The table should be set up in such manner that readings may be taken from both sides of the bar.

MANNER OF USING THE PHOTOMETER.

When one starts to use a new photometer, or one with which the experimenter has not previously worked, the instrument should be carefully verified.

First, make sure that the lines defining the distance between the lights are the proper distance apart and parallel, and that the bar is perpendicular to and midway between them. Next see that the bar is level. The disk must be at right angles to the bar, and the small pointer under the sight-box in line with the disk. The two mirrors should be made of the best plate glass and well silvered. They should be kept clean. The disk should exactly bisect the angle made by the mirrors. The bar should be verified so that the operator may be sure that it is properly divided, and the meter should be tested with a meter prover. In testing the meter be sure that the temperature of the room, of the water in the meter, and of the water in the prover are the same. The pressure gauge should be verified by a U-shaped water gauge. The knife edges of the candle balance should be clean and sharp, and the lever should be free to move without rubbing. The weight for the candle balance should be weighed on an analytical balance to be sure that it is correct.

For testing coal gas no choice is allowed in the burner, but when water gas or any high-grade gas is to be tested it is necessary to get a burner suited to the gas. The most suitable burner can be quickly determined by experiment, and the greatest efficiency is usually obtained with a burner of such size that the gas is almost on the point of smoking. When the photometer light is burned continually, as is usually the case in gas works, the tip on the flat-flame burner should be changed at intervals of two or three weeks. Care should be taken that the tip is smooth. Any tips that are chipped on top or rough in the slot should not be used.

In preparing for a test, the burner and candles should be placed in their proper positions and at such a height that the center of the flames will be on a level with the center of the disk. The height of the candle flame is taken when the candle end of the balance is down. The gas should be burned long enough to be sure that the

apparatus is cleaned out and that fresh gas is being burned. Before starting it is necesssary to control the pressure under the burner so that it will not vary during the test. The governor on the outlet of the meter will do this if it is in order. If the pressure varies, the governor must be cleaned before starting the test. During the test the pressure gauge must be shut off, as in case there is change of pressure it will store or give out enough gas to vitiate the result. The meter should be level and the water at the proper height.

The wicks of the candles should never be touched. The candles are lighted and allowed to burn until the wick curls over to the edge of the flame and burns away as the candle is consumed. The end of the wick should glow. No test should be started until the wicks are bent over and the ends are glowing. The candles should always be burned eight or ten minutes before starting a test. A common practice which gives good results is to allow the candles to burn eight or ten minutes and then extinguish them for two or three minutes. The candles are then relighted and allowed to burn about two minutes before starting the test They are commonly placed in the holders in such a way that the ends of the wicks are as far away from each other as possible.

When the apparatus has been brought to the proper condition for testing, the flow of gas is adjusted to as near 5 feet an hour as possible, and the meter is allowed to run until the twelfth of a foot hand points to o, when it is by-passed. The clock is stopped at o. The candles are counterbalanced by the sliding weight on the balance lever until the weight almost carries the lever down. In a few seconds the candles burn sufficiently to allow the balance to fall, and at that instant the meter and clock should be started. As soon after as possible the 40-grain weight should be dropped into the scale pan, which brings the candles down again. The operator should always move about the room deliberately so as to avoid as far as possible creating currents of air. The candle flames must be still before beginning to take readings.

A reading should be taken every minute for ten minutes. When the screen is apparently illuminated equally on both sides it should be moved a little to the right and to the left, and in each case the illumination on that side should increase. Five readings should be taken on one side of the bar and the sight-box turned around and five taken from the opposite side. In case the bar is

accessible from only one side, the readings should be made with one eye and the screen turned in the sight-box after half have been completed. This will eliminate the errors due to possible difference in the eyes and in the sides of the screen.

The last reading should be taken during the first half of the tenth minute and the times noted when the candle balance falls, and wnen the gas hand completes its tenth revolution. The temperature of the gas and the reading of the barometer should also be noted. After this the candles may be extinguished. They should be blown out and the ends of the wicks extinguished with a piece of sperm. The wicks should never be touched with anything else.

If the candle balance falls in less than 9½ or more than 10½ minutes, or, if the gas hand takes less than 9½ or more than 10½ minutes to make 10 revolutions, the test should be discarded. Long practice has shown that within these limits the light given by the candles varies approximately with the consumption of sperm and that given by the burner approximately with the gas consumed.

If the candles take X seconds to burn 40 grains and the gas hand Y seconds to make 10 revolutions, the average reading multiplied by 2 should be multiplied by $\frac{X}{600} \times \frac{600}{Y}$ or $\frac{X}{Y}$. This will give the candle-power of the gas uncorrected for temperature and pressure.

The standard of pressure is 30 inches of mercury and the standard temperature is 60° Fahr. To correct the pressure multiply by 30 and divide by the barometric reading. In correcting for temperature the gas is assumed to be a perfect gas saturated with water-vapor. The following is the formula for correction for pressure and temperature:

$$n = \frac{17.64\ (h - a)}{460 + t}$$

n = the number by which the observed volume is to be multiplied to reduce it to 30 inches and 60°.

h = the height of the barometer in inches.

t = the temperature Fahrenheit.

a = the tension of aqueous vapor at t°.

The following table will facilitate corrections for various pressures and temperatures.

Table to Facilitate the Correction of the Volume of Gas at Different Temperatures and Under Different Atmospheric Pressures.

Barometer	Thermometer.															
	48°	50°	52°	54°	56°	58°	60°	62°	64°	66°	68°	70°	72°	74°	76°	78°
In.																
28.0	.960	.956	.951	.946	.942	.937	.932	.927	.922	.917	.912	.907	.902	.897	.892	.887
28.1	.964	.959	.955	.951	.945	.941	.936	.930	.926	.921	.916	.911	.905	.900	.895	.890
28.2	.967	.963	.958	.953	.949	.944	.939	.934	.929	.924	.919	.914	.909	.904	.898	.893
28.3	.971	.966	.961	.957	.952	.947	.942	.937	.932	.928	.922	.917	.912	.907	.902	.896
28.4	.974	.970	.965	.960	.955	.951	.946	.941	.936	.931	.926	.921	.915	.910	.905	.900
28.5	.978	.973	.968	.964	.959	.954	.949	.944	.939	.934	.929	.924	.919	.914	.908	.903
28.6	.981	.977	.972	.967	.962	.958	.953	.947	.943	.938	.932	.927	.922	.917	.912	.906
28.7	.985	.980	.975	.970	.966	.961	.656	.951	.946	.941	.936	.931	.925	.920	.915	.909
28.8	.988	.984	.979	.974	.969	.964	.959	.954	.949	.944	.939	.934	.929	.924	.918	.913
28.9	.992	.987	.982	.977	.973	.968	.963	.958	.953	.948	.942	.937	.932	.927	.921	.916
29.0	.995	.990	.986	.981	.976	.971	.966	.961	.956	.951	.946	.941	.935	.930	.925	919
29.1	.999	.994	.989	.984	.979	.975	.969	.964	.959	.954	.949	.944	.939	.933	.928	.923
29.2	1.002	.997	.992	.988	.982	.978	.973	.968	.963	.958	.952	.947	.942	.937	.931	.926
29.3	1.006	1.001	.996	.991	.986	.981	.976	.971	.966	.961	.956	.950	.945	.940	.935	.929
29.4	1.009	1.004	.999	.995	.990	.985	.980	.975	.969	.964	.959	.954	.949	.943	.938	.932
29.5	1.013	1.008	1.003	.998	.993	.988	.983	.978	.973	.968	.962	.957	.952	.947	.941	.936
29.6	1.016	1.011	1.006	1.001	.996	.992	.986	.981	.976	.971	.966	.960	.955	.950	.944	.939
29.7	1.019	1.015	1.010	1.005	1.000	.995	.990	.985	.980	.974	.969	.964	.959	.953	.948	.942
29.8	1.023	1.018	1.013	1.008	1.003	.998	.993	.988	.983	.978	.972	.967	.962	.957	.951	.946
29.9	1.026	1.022	1.017	1.012	1.007	1.002	.997	.991	.986	.981	.976	.970	.965	.960	.954	.949
30.0	1.030	1.025	1.020	1.015	1.010	1.005	1.000	.995	.990	.985	.979	.974	.968	.963	.958	.952
30.1	1.033	1.029	1.024	1.019	1.014	1.009	1.003	.998	.993	.988	.983	.977	.972	.966	.961	.955
30.2	1.037	1.032	1.027	1.022	1.017	1.012	1.007	1.002	.996	.991	.986	.980	.975	.970	.964	.959
30.3	1.040	1.036	1.030	1.025	1.020	1.015	1.010	1.005	1.000	.995	.989	.984	.978	.973	.968	.962
30.4	1.044	1.039	1.034	1.029	1.024	1.019	1.014	1.008	1.003	.998	.993	.987	.982	.976	.971	.965
30.5	1.047	1.042	1.037	1.032	1.027	1.022	1.017	1.012	1.006	1.001	.996	.990	.985	.980	.974	.969
30.6	1.051	1.046	1.041	1.036	1.031	1.026	1.020	1.015	1.010	1.005	.999	.994	.988	.983	.977	.972
30.7	1.054	1.049	1.044	1.039	1.034	1.029	1.024	1.018	1.013	1.008	1.003	.997	.992	.986	.981	.975
30.8	1.058	1.053	1.048	1.043	1.037	1.032	1.027	1.022	1.017	1.011	1.006	1.000	.995	.990	.984	.978
30.9	1.061	1.056	1.051	1.046	1.041	1.036	1.031	1.025	1.020	1.015	1.009	1.004	.998	.993	.987	.982
31.0	1.065	1.060	1.055	1.049	1.044	1.039	1.034	1.029	1.023	1.018	1.013	1.007	1.002	.996	.991	.985

Inasmuch as a flame is not perfectly transparent, a test made with it at right angles to the bar does not give the mean of the light that is emitted horizontally. The richer the gas the greater is the difference between the candle-power measured on the flat and on the edge of the flame. A gas that gives 25 candles measurement flat will not give over 19.5 candles measured on the edge. When the flame is at an angle of 10 degrees with the bar it gives almost as much light as when it is measured at 90 degrees.

The best photometers are made so that the burner may be turned on its axis and the light measured at all angles.

When it is desired to measure the light emitted by a burner at various altitudes, mirrors are used to reflect the light to the disk as the latter is kept vertical and in the same horizontal plane as the standard burner. In such cases it is necessary to test very carefully the amount of light absorbed by the mirrors at all angles.

The foregoing description is intended for those who are not familiar with the photometer. There is a popular impression that photometrical work is not accurate and therefore not to be depended upon, but, if care is taken by the operator in his work, and all the apparatus is properly adjusted, the error will be less than 1 per cent. By taking the average of a series of measurements the error can be reduced to a point where it is inappreciable.

NOVEL EXPERIMENTS WITH X-RAYS.

BY EDWARD P. THOMPSON, M. E., '78.

To Roentgen belongs the credit of discovering the effect of the rays from a Crookes' tube in exciting brilliant fluorescence of barium platino cyanide. He reports particularly an experiment consisting in castinge th shadows of objects with the rays upon a fluorescent screen. The objects he employed were a thousand pages of a book, two packs of cards, tin foil, thick blocks of wood, and a human hand, which was noticed to represent the shadow of the bones darkly, and faintly outline the substance of the surrounding tissue.

On February 1, 1896, it occured to me, and I had the idea attested, that the X-rays could undoubtedly be employed for the investigation of the *movements* of hidden objects. This is a simple idea, and yet it has seemed to have escaped the notice of all experimenters, even of Roentgen himself. I have searched all literature on the subject and can find no reference to it. Before trying the actual experiments I began to think that perhaps I was in error, and experts in this line reminded me that fluorescence remains for a fraction of a second and therefore the shadow might not pass away sufficiently rapidly to prevent a blur upon the fluorescent screen. The experiments were delayed also in failing to obtain the chemical compound necessary, and especially in the form for making a screen. After several experiments I made one in the following manner, and it stood the test of fluorescence with X-rays admirably I took the chemical barium platino cyanide and mixed it with varnish and spread it in coats upon the disk of tracing cloth, and heated and dried it.

This was placed within an opaque tube closed at one end with a double thickness of black paper and open at the other end for the eye to look into. This instrument, which is a kinetoskotoscope, may also contain a lens. The room should be dark to prevent the light in the eyes due to persistence of vision.

The most successful experiments I performed were with the apparatus of Dr. McKay, of the Packer Institute, Brooklyn, N. Y. The induction coil was of very large electrical dimensions, being

adapted to produce sparks of 15 inches or more. The current was taken from the street and regulated by a rheostat. The circuit interrupter of the coil was operated by a small cell, and mercury contacts were employed for interrupting the primary current.

In front of the kinetoskotoscope we placed a bamboo tube. It could scarcely be seen, and appeared like thin glass. Into this tube at opposite ends were introduced two iron rods and they were moved along until they touched, and then they were separated. The shadows of the rods were black and were distinctly outlined and their motions were instantly apparent without regard to rapidity of motion. The application of this experiment, practically in surgery, would indicate the possibility of being able to distinguish a fractured bone from a sprained limb. I know personally of an instance where a servant fell from a roof and was treated ten days for a sprained arm, and then the physician declared that the bone was broken. If the arm could have been examined with a fluorescent screen, the opening or stretching of the arm when held in different positions would have shown the opening and closing of the gap or crack. This is further made evident from the experiments I tried with the finger. When opening and closing it, the individual bones could be seen in motion, and if a bone had been broken the crack would certainly have been apparent.

The bone in the arm is better pictured because thick enough to cast a darker shadow. A pair of wire cutters, upon being opened and closed and invisible by ordinary light, cast black shadows upon the luminous screen. The motion was as apparent as if viewed by natural light. Again, a watch chain was shaken back and forth inside of a heavy black cloth, and the individual links could be seen in motion as to their shadows. An interesting and suggestive experiment consisted in placing behind the hand a large needle and moving it about. The point could be followed to any portion of the hand. The rays passed through the hand and cast the shadows of the bones lightly, of the flesh faintly, but of the needle darkly. Of course if the needle had actually been plunged into the flesh, the appearance would have been the same, because the needle in the actual experiment was on the opposite side of the hand measured from the eye.

In order to determine whether the rays generated from one Crookes' tube could possibly be passed through, and increase the

volume of another tube, the Crookes' tube uncharged was held between the charge tube and the kinetoskotoscope. The German glass was so thin that very little difference was produced. The electrodes and the glass formed a very faint but distinct shadow picture.

The screen fluoresced after the rays had passed through a wooden block 2 inches thick. The light even then was so voluminous that the shadow of a rotating wheel was perfectly clear when held between the block and the kinetoskotoscope. When held on the other side of the block, the shadow was distorted because the wheel was so far away from the screen.

Furthermore, the shadows of moving objects could be seen at a distance of 5 feet from the Crookes' tube.

MIDWINTER MEETING OF THE ALUMNI ASSOCIATION OF THE STEVENS INSTITUTE OF TECHNOLOGY.

The regular midwinter meeting of the Alumni Association was held in Stevens School Hall on Wednesday, February 19, 1896, and was called to order at 8.30 P. M. by the President, Mr. H. de B. Parsons, '84, who stated that he would take this first opportunity to thank the Association for having elected him President, which honor had come to him unsought and unexpected. He also welcomed the members of the Association and their guests.

The chair announced the receipt of a communication from the Lacrosse Team, which was referred without discussion to the Executive Committee. Similar action was taken with regard to the following set of resolutions, presented by the undergraduates, relating to the twenty-fifth anniversary of the Stevens Institute.

RESOLUTIONS OF UNDERGRADUATES.

Whereas, The twenty-fifth anniversary of the founding of the Stevens Institute of Technology occurs in this year of our Lord, eighteen hundred and ninety-six; and

Whereas, The above-mentioned institution was among the first in these United States of America to confer the degree of M. E. on its graduates; and

Whereas, The undergraduate body of the above institution deems it fitting that a suitable celebration be held in commemoration of the same; be it

Resolved, That we, the undergraduates of Stevens Institute of Technology, do co-operate with the Faculty and Alumni of the same, and do commemorate with them the said anniversary in a manner demanded by the importance of the occasion; and be it further

Resolved, That a copy of these resolutions be read before the Faculty and Alumni.

We, the Joint Committee of the Undergraduates of Stevens Institute of Technology, duly empowered so to act, do recommend

The Banjo Club then rendered two selections. The participation of the musical clubs at the midwinter meetings adds greatly to the entertainment of the evening, and the appreciation of this feature of the evening's programme was manifested by the liberal applause accorded to the several clubs on this occasion.

Upon the invitation of the chair the meeting was then addressed by President Morton, Mr. S. B. Dod, President of the Board of Trustees, and Mr. Alex. C. Humphreys, '81.

PRESIDENT MORTON'S REMARKS.

President Morton being first called upon, said as follows:

Gentlemen of the Alumni Association: I find myself on this occasion, as usual, called upon as a sort of "forlorn hope" to lead the attack upon your attention, but as I am always ready to lay down my life in your service, and have also survived many occasions of equal peril, I "take my courage," as the French say, "by both hands" and do not mind.

The resolutions which have just been presented in reference to a twenty-fifth anniversary celebration naturally turn my thoughts back upon our past history and then forward towards our future prospects.

Nearly twenty-five years ago the Stevens Institute began its career with a faculty only half as numerous as it is to-day, and with a number of students too insignificant to mention.

Since then it has gone quietly on without any notable aid or acquisition, growing in dimensions and efficiency, educating for their work half its present Faculty, enlarging its buildings and equipment, never oversupplied with funds, but always able to make two ends meet and to provide such extensions as were imperatively needed.

Our needs have however so far outstripped our means that, as you all know, we are prevented from doing the best work of which we are capable by lack of space.

In this connection I naturally turn from looking backwards to looking forwards, and in the vista of the future seem to see not far off the new building which your liberality has planned and already contributed towards. So soon as our legislators at Washington cease their efforts to shatter the credit of our Government and disorganize our entire system of finance and industry, I believe that a

good time will come when we shall all feel so rich that the erection of the proposed Alumni Building will be an easy task.

By that time also the new photographic discovery will no doubt come to our aid. Already it shows that we need not open purses to get at the coins within, but so far we only get negatives and shadow impressions; but in the hands of Professor Mayer I do not question that improvements will be made by which these will soon be replaced by substantial positives, and that from your overflowing abundance you will be glad to have us take all we may require.

President Morton also announced that in accordance with a resolution of the Trustees last June, arrangements had been made for a course of three lectures on Patent Law, to the graduating class.

These lectures would be delivered in the Institute building at 3 P. M. on three successive Fridays, beginning with February 28. All members of the Alumni Association were cordially invited to attend.

MR. DOD'S REMARKS.

S. Bayard Dod, President of the Board of Trustees, being next called upon, said in substance as follows:

What President Morton has just said concerning the continuous and quiet, but effective development of the Institute during its twenty-five years of life, suggests the thought that all living structures in order to maintain their vitality, or in other words, to continue to live, must continue to grow.

This growth means increase by acquisition. It means to add something to the substance of the individual, or family, or nation, either by development of the environing substance into higher products or the direct absorption of the environment.

As to this latter sort of growth we have recently heard a good deal in connection with a subject not remotely related to the Monroe Doctrine.

The English-speaking race, whether it reside on one side of the Atlantic or the other, has a well defined mission or a "manifest destiny" in this direction, and it would seem as if this "manifest destiny" would be best fulfilled when the United States has absorbed

the two American Continents, and England has appropriated the rest of the world.

But this is not the sort of growth or development which we have now to consider in connection with the Stevens Institute of Technology.

The growth here is rather that which is symbolized by the growth of the good seed planted in good soil and well fertilized and irrigated, or the social and industrial systems which spring from the inspiring ideas of great minds.

Looking back, in this sense, to the germinal origin of the Stevens Institute, I seem to find it in the mechanical genius of Robert L. Stevens, to whom the family owe much of their prosperity as well as their mechanical achievements.

As an engineer he was a pioneer, and what is more, a successful pioneer in the field of railroad-building. It was he who constructed the earliest railroad of any extent in America—i. e., the road from Amboy to Bordentown, operated in connection with steamers running from New York to Amboy and from Bordentown to Philadelphia.

To give you an idea of the primitive character of this most successful railroad, let me mention two incidents.

Among some old documents, which are among the treasures of the Institute, is a letter from George Stevenson, the inventor of the locomotive in England, to Mr. Stevens, expressing his pleasure at receiving an order for a locomotive much heavier than any so far in use in England, which was to be used on this Amboy railroad. The weight of this monster was nine tons.

During the first trip of an earlier locomotive, weighing six tons, the following accident befell. There was a curve on the top of an embankment, where the rails (supported on stone blocks six to each rail) were laid flat—i. e., without elevation of the outer rail. At the foot of the embankment was, at the time when the train came along, a sow with a litter of pigs, and in a field beyond three men cradling wheat. When the train came dashing onward at the fearful rate of six or seven miles an hour, with one of Mr. Stevens' race horses ahead to give warning and clear the road, the locomotive skipped the track and plunged down among the pigs, with a fearful development of squealing as a result. The three men dropped their cradles and did not stop running until they had placed three fields and

three fences between themselves and the pursuing six-ton locomotive.

It was, however, this railroad and this man's work which in a sense laid the preliminary foundation for the Institute.

When, more than twenty-five years ago as the one of Mr. Edwin A. Stevens' executors who was in a position to give personal attention to carrying out the objects of his bequest as to the establishment of an institution of learning, I began to look about me; the problem presented was about this: given—

A plot of ground occupying a city block as a field to cultivate; half a million endowment and $150,000 building fund as fertilizers; how to plant an "institution of learning" which should grow into an adequate monument worthy the mechanical and engineering genius of its founder and his predecessors.

I visited many collegiate institutions and received much advice, but at last in my journey I came to Philadelphia, where I found a young man named Henry Morton occupying the position of chief executive officer of the Franklin Institute, and in him I felt that I had hit upon the seed that would grow and develop from its environment.

Dr. Morton and the eminent men who gathered round and who have worked with him harmoniously and efficiently to the present day, have fully vindicated the choice then made, and by their own work and the work which they have trained others (their pupils, who are now members of our Faculty) to do, have shown how a great and useful institution may grow, not by forcible acquisition, but by the silent and gradual development which proceeds from indwelling vitality of true genius and faithful labor.

Mr. Alex. C. Humphreys then addressed the meeting as follows:

ADDRESS OF ALEX. C. HUMPHREYS

I fear that if I attempt to make any remarks this evening I shall promptly find myself out of order, for, as I understand it, this meeting is not called for the transaction of business, but for social intercourse and amusement. As I cannot expect, however, to make remarks that would in any sense be entertaining, I shall take the liberty of saying a few words to you as to the responsibility of

Stevens Alumni to their Alma Mater. From the time that we develop sufficient discretion to take even a small part in the world's work we carry a responsibility, greater or smaller, towards our fellow beings, and especially towards those with whom our daily life brings us into contact. Those who in our walks through the city streets we brush by without even knowing we bear a responsibility in connection with. We have a very definite responsibility towards our neighbors, towards our city, our State, and our country. Surely, then, we have a definite responsibility in connection with the Institute which has for four years or more borne the responsibility of training us for our life's work. It should be a pleasure for us to remember and respond promptly to that responsibility to the full extent of our individual ability. With some of us I fear that the conscience is satisfied with the reflection that during our college course we or our representatives paid the college $150 per year for our tuition. But a moment's reflection will show that this sum does not pay the actual cost of that tuition. The fact that our college is endowed (though quite inadequately), and in spite of that endowment the college is hardly able to make both ends meet, shows that we have not actually paid our own way by making this annual payment. We are indebted in a measure then to the endowment, provided in this instance by Mr. Stevens. If we have been helped by such an endowment to obtain our education, we in turn should feel the responsibility which rests upon us, to do our best to provide for those who are to come after us. The fact that Stevens is short of funds is due to two causes: First, the decreased earning power of the invested capital; and second, the work of the Institute has been greatly extended owing to reputation made by its Alumni, or in other words, owing to the thoroughness with which Stevens has done its work. This last reason should appeal to every one of us and help us to a keen appreciation of our responsibility in the premises. I fully appreciate that the Alumni as a body is not able to assume a large financial load, but do we not perhaps unduly bring up that fact as a reason for not doing the little we can do? There are those of us who can give $500; there are those of us who can give $400, or $300, and so on down, and there are certainly those who can give five dollars. Some years ago we started the subscriptions for an Alumni Building Fund. It is true that we have in the mean time been through two periods of severe financial

depression, and we have not yet recovered from the last; but I firmly believe with President Morton that a period of renewed prosperity is about to reach us. If the men who in Washington so grievously misrepresent us, and especially in the Senate, can be restrained from further exhibitions of consummate folly, I believe that the country will be able to throw off its burdens, the burdens which, to a great extent, have been, as I believe, imposed by over-legislation. In contemplating the work of our political leaders, Republicans and Democrats alike, it seems to me that judging by their actions, they must feel that if they so desired they could legislate us into Heaven.

During the coming fall we hope to celebrate the twenty-fifth anniversary of Stevens Institute. What time more appropriate could be selected in which to concentrate our energies upon the completion of our Building Fund? Up to date there has been subscribed $14,070.40, the subscriptions unpaid amount to $6,385.65, leaving subscriptions actually paid in $7,684.75. There has also been received the interest from certain bonds, which President Morton has generously set aside in connection with the Institute's work, $3,500, and the interest which has accumulated upon the invested funds, $1,078.48; so that we have a total to the credit of the fund of $12,263.24. We have 477 members, though we should have many more, and it is sad to reflect that there are quite a number who have graduated from Stevens, and who do not sufficiently acknowledge their responsibility to Stevens to maintain their Alumni membership; but the fact that there are these graduates who refuse to acknowledge their responsibility does not relieve us from our responsibility, but rather adds to it. Nearly every member of the Association can help to increase the fund, and especially so if they are willing to exercise self-denial. And it is well to bear in mind that there is no virtue in giving except where self-denial is connected with it. A man may give a million dollars to endow a college, and so doing deprive himself of nothing, but simply relieve himself of part of his burden of care. There is no virtue in this giving. In the selection of a beneficiary he can show such good judgment as to merit our appreciation in that connection, and especially would that be the case if he should decide to give his million to Stevens Institute. It seems to me that with the exercise of the proper self-denial, the following schedule of subscriptions

could be realized, though I acknowledge that it would not be easy to do so :

10	subscriptions	of $500,	$5,000
20	"	" 250,	5,000
30	"	" 125,	3,750
40	"	" 75,	3,000
50	"	" 50,	2,500
75	"	" 25,	1,875
100	"	" 10,	1,000
125	"	" 5,	625

Making a total of $22,750

and leaving 37 members with no subscriptions put against them. The amount we now have in hand is $12,263; adding this amount we should have then $35,013. If in addition to these new subscriptions we could also collect the back subscriptions not yet paid, $6,385, we should have a total of $41,398, and with that amount in hand we could easily see daylight ahead. This is a large undertaking beyond all question, but it is not beyond our powers if we, one and all, properly realize our responsibilities to our Alma Mater. Until we do take hold of the work ourselves we cannot expect that others will come forward to assist us, nor should we expect it. President Morton's generosity to the Institute in this connection should teach us our lesson and we should also learn a lesson from the interest that is being displayed in this matter by our undergraduates.

It may seem foolish to suggest more work for the Alumni Association when so much yet remains to be done on the Building Fund, but it seems to me that it is well that we should not regard our responsibility as one to be met by a single spasmodic effort, but that we should be willing to feel that our duty to the Institute is a constant one. What I would now refer to I have very close to my heart, but I fear that I have not the ability to lay it before you with sufficient delicacy. Twenty-five years ago our honored President brought with him to the Institute certain professors, and these professors are almost without exception yet with us and doing their work. We want them with us just as long as they can carry on their work without their feeling it as an absolutely wearisome burden. But when we remember the twenty-five years which have elapsed we are forced to conclude that before very many years

some of them must lay down at least part of their burden. Whether they retire either wholly or in part, they should, under certain proper provisions, be retired with an income, and for this the Institute needs a retiring fund. I would therefore suggest that we not only have in mind our Building Fund, but that we have in mind to take up a still greater work when the Building Fund is completed, namely, the accumulation of $100,000 as a retiring fund. This is a large sum, no doubt, for us to raise, but it is small enough for the purpose referred to. I wish that I could bring this subject before you in a way to make the deepest impression upon you, for I repeat that it is very close to my heart, and possibly this may be partly due to the fact that I am the son of an educator. I trust that during the year we shall make an earnest effort to carry through our building-fund scheme to a successful termination. And I hope that we shall then have the courage to take up the greater work which I have just outlined.

At the close of Mr. Humphrey's remarks the Glee Club sang two selections, after which Mr. John W. Lieb, Jr., 'So, was requested to address the meeting. In responding, he said:

MR. LIEB'S REMARKS.

It is but natural that in the pursuit of a profession so eminently utilitarian in its character as the one we have selected for our life's work, we should develop a strong tendency to look at things from a purely mechanical standpoint; from the point of view of successful adaptation of means to an end.

While undoubtedly the most important requisites of all engineering construction are utility, efficiency and durability, the successful constructer will not altogether neglect the superiority which these features assume when presented, as Lucian says, " in forms pleasing to the eye, with a happy choice of dimensions and a just relative proportion of parts to the whole."

We, too, have been taught by eminent instructors that in planning any mechanical construction, pleasing design, harmonious proportions, and graceful curves are not incompatible with structural strength, minimum weight of material, or low manufacturing cost.

The ancients considered no product of the artisan too insignificant to be presented in pleasing forms and the graceful and ele-

gant designs of the tripods, surgical instruments, scales, jugs, ladles and kitchen utensils of all kinds, dug from the ruins of Pompeii, bear able testimony to the good taste and inventive faculty of the humblest metal-workers of that unfortunate city. This artistic sense is more generally developed on the Continent than with us, but there it finds its exemplification rather in the industries allied to the fine arts, than the useful products of the mechanical artisan.

It is with the products of the workshop rather than the workbench, that American genius has achieved its greatest triumphs, and each successive international exposition has demonstrated that American machinery leads the world in originality and excellency of design, construction, and workmanship. That the American manufacturer is, on the other hand, alive also to the importance of catering to the specific tastes of the buyer, is evident from the gorgeous hues and chromatic aberrations often displayed on agricultural machinery.

I know of an instance in a Latin country where a keen agent for an American manufacturer of agricultural machinery, instructed him in decorating his product to be less partial to one end of the spectrum, as his peasant customers also admired vivid contrasts in the shape of blue, green, and yellow. It is needless to say that in this case the Yankee spirit of trade triumphed over all æsthetic obstacles, and that the agent was promptly accommodated.

I might cite also an interesting experience in a beautiful city, while directing the construction of the first example in that region of that most unæsthetic but eminently useful modern development —the electric trolley road. According to the terms of the municipal concession, the construction of this road, in all details, was to be submitted to the inspection and approval of a special committee of councilmen. This committee consisted of an eminent cathedral architect, a celebrated painter, a polytechnic professor, and a retired banker. It would lead me too far afield to recount the herculean efforts made to satisfy this formidable array of critics with the design and location of the ornate poles and brackets and the somewhat less ornate overhead wires with their maze of frogs, turnouts, span wires, guys, etc. The "pièce de résistance," however, came with the trolley car itself. It took no less than three long sessions of that august committee to select the appropriate color and striping for the car panels. Some parts of the electrical equipment of the

car had not yet arrived and the committee was therefore still in blissful ignorance as to what a trolley looked like. It was agreed that at the final inspection the car should be presented completely equipped with trolley, controller, headlights, and auxiliary apparatus, a wire being stretched above the car to show the position the trolley pole assumed in actual service.

Words fail me to describe the look of consternation depicted on the faces of that committee, as they gazed for the first time "on that horrible broom sticking out of the top of the car," as one of them described the innocent looking trolley pole.

It availed little to explain to the committee that thousands of patents had been taken out by ingenious Yankee inventors for all sorts and kinds of over-running and under-running trolleys, and that what they saw before them represented the survival of the fittest. Then and there, they proceeded to make suggestions for impracticable modifications with a view to improving the appearance of the offensive trolley, and only reluctantly gave it up and accepted the inevitable, not without insisting, however, that for the brand new and shining white trolley cord, a thinner black cord must be substituted as being less in evidence.

Notwithstanding occasional tendencies like these to render utility subservient to appearance, the influence of a sound artistic sense in rendering all classes of engineering construction more pleasing to the eye, is wholesome and should be cultivated. We should lose no opportunity to study classic types and to closely observe engineering and architectural construction, and products of the mechanic arts of acknowledged excellence and purity in design and execution. The attempt to render ornate, simple and severe constructive features, requires the exercise of the greatest care and, unless controlled by a critical eye and guided by an experienced hand, the effect may be the reverse of what is desired. Careful observation and critical comparison serve to develop a style which can make itself felt in the pleasing presentation of even the severe lines of mechanical design.

Let us then pause occasionally in our mad chase after the almighty dollar, in the pursuit of utilitarian schemes, in the shaping of cold metal and the tussle with hard facts; let us turn aside a moment to admire and learn to appreciate the beauties which Nature

and art have spread before us, and develop our appreciation and love for the beautiful and the good.

"For this is art's true indication,
When skill is minister to thought,
When types, that are the mind's creation,
The hand to perfect form had wrought."
(Storey's Theory of Strains)

The Mandolin Club then rendered two selections and was followed by Mr. F. R. Harris, '96, Manager of the musical clubs, who announced the coming concert of these clubs to be given at Chickering Hall, New York City, March 3, 1896, for the benefit of the Alumni Building Fund.

The Glee Club again favored the meeting by singing "The Mechanical Engineer," many of the Alumni joining in the chorus, and then adjournment followed.

The remainder of the evening was spent in partaking of an excellent collation and in general good-fellowship, advantage being taken by many of the opportunity to become acquainted with their fellow-members.

List of members in attendance:

President Henry Morton.
Prof C. W. MacCord.
J. M. Cremer, '76.
A. Riesenberger, '76.
A. P. Trautwein, '76.
F. E. Idell, '77.
E. P. Roberts, '77.
J. W. Lieb, Jr., '80.
W. P. Parsons, '80.
D. Woodman, '80
A. C. Humphreys, '81.
F. C. Fraentzel, '83.
H. A. Hickok, '83.
M. McNaughton, '83.
W. H. Bristol, '84.
D. S. Jacobus, '84
W. L. Lyall, '84
H. Mitchell, '84.
H. de B. Parsons, '84.
H. S. Prentiss, '84.
J. M. Rusby, '85.
F. E. Jackson, '86.
O. F Pfordte, '86.
R. M. Anderson, '87.
J. A. Davis, '91.
L. H. Nettleton, '91.
H. W. Smith, '91.
H. W. Jackson, '92.
F. E. Law, '92.
H Löwenherz, '92.
W. O. Ludlow, '92
H. C. Meyer, Jr., '92.
A. J. Post, Jr., '92.
H. D. Reed, '92.
C F. Vogelius, '92,
F. L. Waefelaer, Jr,, '92.
H. H. Adams, '93
B. G. Braine, '93.
A. B. Brookfield, '93.
O. G. Dale, '93.
F. D. Furman, '93.
A. Hupfel, '93.
H. Kopp, Jr., '93.
E. D. Lewis, '93.
F. L. Parker, '93.
C. T. Rittenhouse, '93.
J. Cottier, '94.
J. W. Gilmore, '94.

J. H Cuntz. '87.
J. D. Flack, '87
R. Beyer, '88.
G. Campbell, '88.
N. St. Geo. Campbell, '88.
G. Dinkel, Jr., '88.
P. Doty, '88
E. Ducommun, '88.
A. S Miller, '88.
H E. Reeve, '88.
J. Eastwood, '89.
H. L. Ebsen, '89.
F. Gubelman, '89.
N. H. Hiller, '89.
W. D. Hoxie, '89.
R. C. Oliphant, '89.
J R. Onderdonk, Jr., '89.
S. Boyer, '90.
J. S. De Hart, Jr., '90.
W. Ebsen, '90.
C. J. Everett, Jr., '90.
W. M. Farrar, '90.
E. W. Frazar, '90.
G. L. Todd, '90.
W. S. Ackerman, '91.
E Gnade, '94.
M. W. Kellogg, '94.
C. C. Kenyon, '94.
H. D. Lawton, '94.
A. M. Lozier, '94.
C. W. MacCord, Jr., '94.
E. D. Mathey, '94
G. Rosenbusch, '94.
R. W. Smith, '94.
P. Allan, '95.
G. E. Bruen, '95.
T. B. Cuming, '95.
A. F. Ganz, '95.
E. Hutchinson, '95.
B. H. Jackson, '95.
F. N. MacVeety, '95.
E. W. Robinson, '95.
E. C. Schmidt, '95.
C. J. Slipper, '95.
F. N. Taft, '95.
F. K. Vreeland, '95.
F. W. Walker, '95.
A. R Williams, '95.
H. C. Zimmermann, '95.

The Banjo, Glee, and Mandolin Clubs were represented as follows:

BANJO CLUB

R. L. Messimer, '97.
G. P. Richardson, '97.
J. F. Hunter, '97.
A. Beutler, Jr., '97.
H. C. Messimer, 96.
A. C. Woodward, '96.
E. C. Warren, '97.
A B. Upjohn, '99.
G. L. Hutchins, '97.
H. L. Hardie, '96,

GLEE CLUB.

E. D. Kellogg, '98.
A. Macdonald, S. S.
W. H. MacGregor, '96.
R. L. Messimer, '97.
O. A. Pope, '96.
E. J. Munby, '97.
E. L Decker, '96.
H. C. Messimer, '96.
R. Bruckner, '96.
G. D. Williamson, '97.
J. Van Brunt, '97.
G. Hewitt, '96.
P. D. Wagoner, '96.
C. Peck, '99.
E. Campbell, '99.

MANDOLIN CLUB.

Geo. Kollstede, '97.
J. P. Evertsz, '96.
J. R. Westerfield, '99.
H. C. Mathey, '97.
E. N. Wood, '97.
R. C. Post, '96.
A. W. Gunnison, '96.
J. F. Hunter, '97.
G. L. Hutchins, '97.
S. A. Hasbrouck, '97.
D. Gregory, S. S.
B. Bumsted, '96.
L. J. Borland, '96.
L. B. Lent, '97.
E. T. Powers, '97.
M. S. Hart, S. S.

INSTITUTE NOTES.

A COURSE OF THREE LECTURES on Patent Law was delivered to the Senior Class by Mr. Richard A. Dyer, of the firm of Dyer & Driscoll, Patent Solicitors, of New York City, on three successive Fridays, beginning February 28, 1896. The first lecture was devoted to an explanation of what is considered an invention, the method of procedure for obtaining a patent, the form of an application for a patent, and the subject of patent interferences.

The second lecture covered the questions of the term of American patents and how it is affected by the issuance of foreign patents; of the joint ownership of patents; the reissuing of patents; disclaimer; grants, and licenses. The lecturer emphasized the importance of written contracts between the joint owners of patents, and, in the case of grants and licenses, between the parties concerned.

In his last lecture Mr. Dyer took up the subject of infringements and cited several important suits to recover damages which were unsuccessful. The patentee, he said, should, in infringement cases, apply for an injunction, temporary or permanent, to stop the further use, manufacture, or sale of his invention.

The full term of 17 years is secured to an American patent, in case a foreign patent is also applied for, if the American and the foreign patents are granted at the same time.

The lecturer treated the more important matters relating to Patent Law at length, and made many practical suggestions to inventors. His extensive experience and concise and forcible mode of expression enabled him to present the subject in a very comprehensible and interesting manner.

THE FACULTY OF THE INSTITUTE sent a memorial to the Congress of the United States, in support of the Bill now pending, and entitled "A Bill to organize and increase the efficiency of the personnel of the Navy, &c." H. R. 3618.

This Bill, as noted in the January INDICATOR, has for its object the extension of appointments in the engineering service of the Navy to civilians. The memorial, which was submitted to both Houses of Congress, was as follows:

"In the first place we would say that in the proposed action of Congress the Stevens Institute of Technology has no direct interest and would not receive any benefit in any way as a result of the passage of the Bill referred to. We are actuated only by our sense of duty as citizens who have at heart the prosperity, safety, and honor of our country, and the conviction

that facts are known to us which may aid in the intelligent treatment of the subject involved.

In the first place we assume that it has been satisfactorily shown by others that an increase in the personnel of the Corps of Naval Engineers, as regards numbers of adequately trained men, is required and that the only question demanding further consideration is the method of securing this increase.

Of the various methods which may be suggested to this end, the only one we feel ourselves competent to discuss is that which involves bringing the graduates of Technical Schools, who send out competent Mechanical Engineers, into the service of the United States Navy as Engineers. In this relation we are of the opinion that the Bill referred to opens an available door and affords adequate encouragement to induce a moderate number of such graduates to enter the service of the United States Navy as Engineers.

During the 25 years of its existence, the Stevens Institute of Technology, has graduated about 550 Mechanical Engineers, very many of whom have achieved high reputation in their profession and are now occupying responsible positions as managers and superintendents of industrial establishments in which their ability as Mechanical Engineers is fully utilized. A considerable number of these have been and are engaged in the construction and operation of marine engines and structures, but with one exception none of them has gone into the service of the Navy Department.

The exception above noted is one of those which 'prove the rule,' for this was one of our early graduates, who, after leaving here, was willing to make a fresh start, and entered the Naval Academy as a Cadet, thereby, of course, sacrificing several years by repeating in form most of the studies in which he was already proficient.

It is because we believe that the provisions of the Bill here considered will induce capable graduates of Engineering Schools to enter the service of the Navy Department that we take the liberty of addressing to your honorable body the above memorial."

THE TEN HORSE-POWER ROTARY TRANSFORMER, ordered last June of the Westinghouse Company, by the Class of '95, has at last arrived, and has been set up in the dynamo-room. It is a four-pole machine, compound-wound, provided with a commutator on one end, and with four collector rings on the other end. Driven with power, it can furnish two-phase alternating currents at 110 volts pressure in each phase; or furnish direct current at 125 volts pressure; or it can furnish both at the same time. The machine can also be used as a direct-current or as a two-phase alternating-current motor; finally, a direct-current may be supplied at one end, and a two-phase alternating current taken off at the other end, or *vice versa*.

Its chief use at present is to furnish two phase alternating currents for experimental purposes.

One of the two 500-volt generators, recently rebuilt at the Institute, has been provided with three collector rings, suitably connected to the armature winding, to supply three-phase alternating currents.

A WORKING MODEL OF A MULTIPHASE INDUCTION MOTOR has also been constructed. The field of this model is wound in twelve sections, which may be connected in various combinations, adapting it for two, three, or four-phase circuits. The shaft is vertical, provided with a horizontal ball bearing; the weight of the armature is thus made to rest on the steel balls, reducing friction to a minimum. Cylindrical masses of iron, copper, or any conducting material may be used for armatures; very good results were obtained with an ordinary iron pulley. These armatures are self-starting and acquire a high speed, developing considerable power. A number of closed coil armatures will be constructed, illustrating various forms of winding With two and three-phase currents on tap, and with the motor model above described, the study of this important part of the subject is greatly facilitated.

A LARGE RHEOSTAT, about 5-foot cube, having a resistance of several thousand ohms, and a carrying capacity of about five ampères, was presented to the Electrical Department through the kindness of Mr. E. W. Frazar, '90. This will be found useful for many purposes.

Mr. Percy Allan, '95, presented the department with an electrophorous of his own construction.

It is hoped to obtain further additions to the laboratory from the Alumni.

MR C J FIELD, '86, delivered an interesting lecture on February 5, 1896 to the Senior Class, the subject being "The Cost of Generating a Kilo-Watt Hour in Central Stations."

The lecture was of a most practical nature, including details not found in text-books. Mr. Field reviewed the history of lighting stations, pointing out the important steps in the development, and leading finally up to the modern station with its 2,500 horse-power direct-connected generators. The lecture was part of an article by Mr. Field which appeared in the March number of *Cassier's Magazine*.

ON THE 12TH OF MARCH, Professor Mayer completed experiments which show conclusively that the Roentgen rays cannot be polarized.

When plates of crystals of iodo-sulphate of quinine are superposed so that their axes cross at 90°, the crossed plates appear *black*, even when these plates are only $\frac{1}{800}$ inch thick. The light which has gone through the upper plate is completely polarized, and therefore cannot go through the plate under it whose axis makes 90° with the upper plate. Therefore, if the Roentgen rays are polarizable, these black portions of the crossed plates should act like lead to the Roentgen rays and completely screen them from the photographic plate.

The fact is that the Roentgen rays are not, in the least degree, screened by the crossed plates; thus showing in a very satisfactory manner, what

Roentgen showed by his experiments, viz: that X rays are not polarized by passing through doubly refracting substances.

The Journal of the American Society of Naval Engineers for February, 1896, contains Professor Denton's paper on "The Reliability of Throttling Calorimeters," which was presented at the New York meeting of the American Society of Mechanical Engineers, December, 1895.

The same number of this journal contains Professor Jacobus' article on "Measurement of Temperature of Steam," which was published in the INDICATOR for January, 1896.

THE SUMMER SCHOOL OF MODERN LANGUAGES, at Point O' Woods, N. Y., which is under the direction of Professor Kroeh, announces its third season from July 6 to August 14. 1896. Courses in German, French, Spanish, and Italian are offered.

PROFESSOR BRISTOL HAS PERFECTED a Recording Thermometer for measuring atmospheric ranges of temperature.

The novel and valuable feature of the instrument is that the recording portion may be located at a distance of 25 or 30 feet from the point at which the temperature is to be measured.

The bulb portion of the thermometer consists of a set of helical tubes these tubes, the pressure tube of the recorder, and the capillary tube con necting the bulb and recorder, are filled with alcohol.

These instruments should prove useful for cold-storage plants, drying-rooms, etc., where a continuous record of temperature is desired.

PROFESSOR MANNING HAS CONTRIBUTED an article to "Life" upon the University of Berlin, in which he treats of the methods of study and contrasts the difference between an American college and an European university.

MESSRS. B. F. HART, JR., '87, AND E W. FRAZAR, '90, who were appointed a committee to organize an Engineer Division of the Naval Reserve of New Jersey issued a circular outlining the work it is proposed to do, which stated: "We propose to give the men practical and theoretical instructions in the running of the engines, and general management below decks of ferryboats, tugboats, and modern warships; a comprehensive course of study and practice in the manipulation and principles of electricity in all its branches, particularly that relating to the winding of armatures, dynamo construction, and general wiring; practical instruction in the running of trolley cars, and knowledge of distribution of power and arrangement of plant of a city system; locomotive engines, their construction and detail; torpedo practice and planting of mine fields under the supervision of experts; the Army and Navy codes of signals; the Morse telegraph and the installation of field telegraph and telephone lines, and instruction in infantry and artillery tactics.

In its entirety, this is a grand opportunity for young men to gain not superficial knowledge, but actual experience in all the above interesting subjects, and solely at the expense of personal time and application.

We are extremely desirous of getting together a congenial group of men, who, by working with the harmony that characterizes a perfect engine, may make for themselves a name in the service, and add greatly to the efficiency of a part of our military system, that is growing very steadily."

About 30 undergraduates attended a meeting held on board the U. S. S. Portsmouth, foot of Fourteenth Street, Hoboken, on January 20, 1896, to talk over the subject proposed.

THE TREASURER OF THE ALUMNI ASSOCIATION has sent a copy of the subjoined resolution, which was passed by the Executive Committee of the Association, January 9, 1896, to all members in arrears for dues. The result has been gratifying, many members having already responded. It is hoped that the remaining delinquents will remit before the July INDICATOR is issued.

Resolved, That the Treasurer be authorized to insert in the July number of the INDICATOR the names of all members of the Alumni Association who are in arrears for dues for a period of one year or more, provided that the proper notices, as called for by the Constitution, shall have been mailed to their addresses and that they be informed with the last notice that such a list will be published.

THE ENGINEERING SOCIETY held its first meeting of the term on Friday, January 24. Professor Mayer delivered a lecture on "The Effect of Temperature on the Modulus of Elasticity, and Variations of the Same," in which he gave some results of his three years' work upon the subject. He also spoke of the acoustic properties of aluminum, and made experiments to illustrate this subject. Mr. Dickerson, '96, reviewed the mechanical journals. The meeting was well attended.

On Friday, February 14, the second meeting was held, at which Mr. Hutchins, '97, read a paper on the "Westinghouse Air-Brake System."

THE SEVENTH ANNUAL LANTERN SLIDE and Print Exhibit of the Stevens Photographic Society was held in Stevens School Hall on Wednesday evening, February 26, 1896. A large audience was well entertained by the exhibition of a great variety of slides, prepared by different members of the Society, of scenery of this and foreign countries. In addition to the lantern slides the program included music by the Mandolin Club, a Whistling Duet, by Messrs. Steinbrügge, and a tenor solo, by Mr. William MacGregor.

President Morton, in awarding the prizes made mention of the utility of photography, more particularly with reference to engineering.

The first prize was awarded to L. M. Azavedo, '99, the subject being a coffee plantation scene. A group pictured by E. N. Wood, '97, received second prize. The slides were explained by Mr. E. J. Munby, '97, Vice-President of the Society.

A considerable portion of the walls of the room was covered with mounted pictures, which attracted a great deal of attention and upon which favorable comment was made.

THE CONCERT GIVEN by the Glee, Banjo, and Mandolin Clubs, at Chickering Hall, New York City, on Tuesday, March 3, 1896, for the benefit of the Alumni Building Fund was successful in every respect. A large and appreciative audience, including many Alumni and their friends, were present and applauded the clubs, whose performance gave every evidence of very thorough preparation.

The concert was considerably extended, owing to the fact that every number of the program was encored.

The proceeds of the entertainment will probably amount to $400; one half of this sum will go to the Building Fund and the other half to the Musical Clubs.

THE S. S. S. HELD A DANCE on January 28 Every one had a pleasant time, including a number of the Alumni who were present. The Patronesses were: Mrs. H. Morton, Mrs. A. M. Mayer, Mrs. T. B. Stillman and Mrs. Smith.

ON THURSDAY, JANUARY 30, THE MUSICAL CLUBS gave their first concert before the public at Hasbrouk Hall, Jersey City. A large number of the fashionable people from the Heights were present, and when after the concert the chairs were cleared away, the floor was covered with dancers till the early hours of the morning.

ON FEBRUARY 13 THEY GAVE A CONCERT and dance at Montclair, and later another at Orange. Owing to the inclemency of the weather the audience in both instances was small; yet those who came spent a very enjoyable evening.

The Clubs gave a concert before the New Jersey Athletic Club, at Bayonne, on February 12. The audience was large and enthusiastic.

The Mandolin Club assisted at a concert given by the Essex Infantry of Newark, on February 14, and at the Jersey City High School, on the afternoon of the 19th.

THE THEATRE PARTY of the Sophomore Class was held at the Lyric Theater, Hoboken, where a large and appreciative audience laughed at "Rush City." The best of good feeling was displayed between the Sophomores and the Freshmen, there being no demonstration of any kind except a few rousing yells between the acts.

PRELIMINARY DANCE CARDS for the Junior Ball, which takes place on the 17th of April, have already been issued.

THE SENIOR BANQUET took place at the Marlborough, on Thursday, February 27 At this dinner the Life Inter-class Football Banner was presented by Mr. Boucher, representing the committee, Messrs. Kidde and Miller.

THE SOPHOMORE BANQUET was held at the Marlborough, on Friday, March 6.

ATHLETICS.

AT THE ANNUAL MEETING of the Athletic Association the following officers were chosen:

President, Gordon L. Hutchins, '97.

Vice-President, William E. Mallalieu, '97.

Secretary, O. R. De Lamater, '98.

Treasurer, R. S. Scott, '98.

Executive Committee: J. F. Hunter, '97; Emil Frank, '98; F. D. Kennedy, '98.

A Coach has been secured for the Lacrosse Team.

The Annual Convention of the Intercollegiate Lacrosse Association of the United States, was held at the Hotel Lafayette, Philadelphia, on February 13. The delegates from the three colleges composing the Association were: B. M. MacDonald, Captain, and O. J. MacKnight, Manager of the Lehigh Team; M. W. Hill, Captain, and Dudley Williams, Manager of the Johns Hopkins Team; W. H. Jennings, Jr., Captain; W. E. Mallalieu, Manager, and J. F. Hunter, of Stevens.

The arrangement of championship games decided upon is the following:

May 9, Stevens *vs.* J. H. U., at Hoboken.

May 16, J. H. U. *vs.* Lehigh, at Baltimore.

May 25. Lehigh *vs.* Stevens, at South Bethlehem.

The championship of 1895 was formally awarded to Lehigh.

The election of officers followed:

President, B. M. MacDonald, Lehigh.

Vice-President, Dudley Williams, J. H. U.

Secretary and Treasurer, W. H. Jennings, Jr., Stevens.

Executive Committee: M. W. Hill, J. H. U.; W. E. Mallalieu, Stevens.; O. G. MacKnight, Lehigh.

Discussion followed on the eligibility of two men in last year's J. H. U.–Stevens game. It was decided that if questions of eligibility cannot be settled by correspondence, that a special meeting of the Association be called and its decision be final.

The Freshmen Baseball Team had a meeting Friday, January 24, and H. R. Sanson, the recently elected Manager of the team, resigned, G. H. Stover, Jr., being elected in his stead.

The Freshmen have challenged the Freshmen teams of all the surrounding colleges.

INSTITUTE PERSONALS.

'75.

A. SORGE, JR., is active upon a committee of organization in the formation, in Chicago, of the "Technical Club," which is to be conducted somewhat on the lines of the Engineers' Club of New York City.

'76.

THE *American Machinist*, January 16, 1896, notes the acceptance by Gus. C. Henning of a position with the Department of Buildings in New York City, and states that his experience and knowledge of materials and tests will be useful in an effort that will be made to correct some of the anomalies that exist in that department.

WM. KENT delivered a lecture on Engineering and the Labor Question before the Department of Engineering of the Brooklyn Institute of Arts and Sciences, January 24, 1896.

'77.

THE National Meter Company, 298 Broadway, New York City, is building a two-cylinder gas engine designed by LEWIS H. NASH. *The Iron Age* of January 16, 1896, contains an illustration of one of these engines, of 20 horse-power, with the following description: "The engine is of the four-cycle type, but owing to the arrangement of the valve eccentrics and the cranks, an ignition takes place at each revolution. This construction, in connection with a very sensitive governor, insures the close regulation and steady running of the engine. The inlet and exhaust valves are of the poppet type and are actuated by eccentrics carried by a secondary shaft extending across the front of the engine case. The air valve rod is moved by the same eccentric as the gas valve. The stem of the latter is so located as to be operated by a pawl controlled by the governor, which is mounted in the flywheel. This pawl is pivoted to a bar projecting from the rod of the air valve, but it does not come in contact with and move the gas valve except when the speed is reduced and the action of the governor brings it in line with the gas valve rod. All the valve mechanism is contained in a separate chest secured to the top of the cylinders. The oiling of the engine is entirely automatic, the crank pin and main bearing being flooded with oil when the engine is running. The crank shaft is made of forged steel, and runs in phosphor-bronze bearings, which can be readily adjusted, access to them being afforded through a large door in the frame of the engine which is held in place by two clamp screws. A device is provided by means of which the engine can be started easily. The regulation of the engine is so close that it can be used for electric lighting, and when so used can be coupled directly to the dynamo."

'78

OSCAR ANTZ is contributing a series of articles on the "Construction and Maintenance of Railway Car Equipment" to the *American Engineer, Car Builder and Railroad Journal*, in which he describes the improve-

ment made in railway car equipment in the last few years, and outlines the possible changes which may take place in the near future. The first of these articles appeared in the January, 1896, number of the above journal.

'79.

PHILIP WALLIS is Master Mechanic of the Lehigh Valley Railroad, Hazleton, Pa.

'80

JOHN W. LIEB, JR., Assistant General Manager of the Edison Electric Illuminating Company, of New York, delivered an address on "The Generation and Distribution of Current by an Edison Station" at the 172d meeting of the New York Electrical Society, which was held at the Duane Street Station, New York City, of the above Company, on Thursday, February 27, 1896. Mr. Lieb is the President of the Society.

THE FIRM OF HUMPHREYS & GLASGOW has just contracted for a complete set of water-gas apparatus, including the water-gas plant proper, station meter, oil tank and iron operating floor for the Gas Works at Holyoke, Mass.; this plant will have a capacity of 500,000 cubic feet per day. Humphreys & Glasgow have also well under way two sets of 350,000 feet each for the gas company at St. Joseph, Mo., and have about completed a plant of 1,000,000 feet per day for the Central Gas Light Company of New York City and one of 350,000 feet a day for the Gas Company at Newburg, N. Y.

In Europe, in addition to many plants previously erected, the firm has just completed a plant for Brighton of 1,500,000 feet per day, and another for Bath of 1,000,000 feet per day.

Besides the above they have five or six plants, with capacities ranging from 500,000 to 3,500,000 feet per day, well under way. The larger ones of these are for Belfast and Manchester.

'81

EDWARD E. MAGOVERN is Manager of the Yale & Town Manufacturing Company, at Branford, Conn.

'82

GEORGE GIBBS, who is a member of the Western Railway Club, attended the January meeting of the Club, held at the Auditorium Hotel, Chicago, Ill., on January 21, 1896, and participated in the discussion of the paper which was before the meeting.

AN INTERESTING ARTICLE on the Edison Electric Illuminating Company of New York by Joseph Wetzler, appeared in *The Electrical Engineer*, January 8, 1896.

The article begins with an historical account of the development of this company, and describes at length the equipment and operation of the various lighting stations located in New York City.

The subject is exhaustively treated and is liberally illustrated.

'83.

MORGAN BROOKS is President and Manager of the Electrical Engineering Company, Minneapolis, Minn.

L. S. RANDOLPH read a paper on "Cement Testing" at the regular meeting of the Association of Engineers of Virginia, held at Roanoke, Va.,

Saturday, November 23, 1895. The paper referred specially to the effects of heat upon the strength of cements.

'84.

C. L. GATELY is General Manager of The United Wood Gas Company, 104 Wall Street, New York City.

Cassier's Magazine, March, 1896, contains an article by ALEX. J. WURTS on the "Protection of Electrical Apparatus Against Lightning," and one by H. DE B. PARSONS, entitled "The Expert Engineer."

S P. BUSH is a member of the Progressive Railroad Club, whose members are employees of the P. C. C. & St. L. R. R. He is also a member of the Western Railway Club, attended its meeting held at Chicago last January, and took part in the discussions of papers presented to the meeting.

The Bond Record, New York City, December, 1895, published a long article by ERNEST S. CRONISE, giving the History, Location, Physical Characteristics, Terminals, Traffic and Finances, of the Baltimore and Ohio Railroad System.

The article is interesting in several respects: The points brought out under the headings Location and Physical Characteristics were not generally known and had not been fully appreciated. The treatment of the subject of finances of this railroad is particularly interesting. As information regarding the finances was not readily available and not obtainable from the officers of the company, the problem of preparing a correct statement of its financial condition presented serious difficulties. Mr. Cronise has, however, by a careful and thorough analysis of the financial statements, issued by the officers of the company, been able to make a report, which contains information that should prove of great value to those whose interests are involved in the future development of this great railway system.

The Baltimore and Ohio Railway article is the first one of a series on our leading railway systems, which, as Consulting Engineer for *The Bond Record*, Mr. Cronise is preparing for this paper.

The Erie Railway System will be the subject of the second article.

THE ARTICLE BY JOSEPH WETZLER upon the Edison Illuminating Company, of New York, noted above, in describing the engines used, states that the consideration of economy in space led to the adoption of a type of engine designed by J. Van Vleck, the chief electrician and constructing engineer of the company. The essential features of the design consist in locating the steam chests in front of and not between the cylinders and in the use of radial valve gear. An engine of this design will occupy only two-thirds the length of an engine as ordinarily constructed. The article quoted also refers to the "Edgewise System," devised by Mr. Van Vleck, as the most original and distinctive feature of the operating-room. According to this system, instead of moving field regulating switches and meter index hands around the flat face of a circle, these are handled or read on the edges of a quarter-circle.

H. L. GANTT has been engaged for the past ten months as Superintendent of the American Steel Casting Company, and is now in charge, in this capacity, of its Norristown shops.

'86

JAMES S. MERRITT is with the firm of Merritt & Co. (formerly Rutter & Merritt), manufacturers of ornamental iron and wire work, 1024 to 1028 Ridge Avenue, Philadelphia, Pa.

CHARLES RUSSELL COLLINS is Vice-President and General Manager of the Manhattan Incandescent Light Company, 931 Broadway, New York City.

EDWIN J. COOK is Electrical Engineer of the Cleveland Electrical Railway Company, Cleveland, Ohio.

AN ARTICLE BY C. J. FIELD on "Development of Electric Power Stations" appeared in *Cassier's Magazine*, March, 1896.

'87

WALTER S. DIX is in the employ of the Stanley Electric Manufacturing Company. Since last November he has been Assistant to the Engineer of Works, Royal Electric Company, Montreal, Quebec, manufacturers of Stanley—"S. K. C."—apparatus for Canada. This company also manufactures single-phase alternators, direct-current motors and generators, and arc lamps and arc machines.

CRAWFORD WHEATLEY is City Engineer and Superintendent of Water-Works, Americus, Ga.

JOSEPH A. MCELROY, of the firm of Macartney, McElroy & Co., Consulting Engineers and Contractors, 1302 Havemeyer Building, New York City, makes a specialty of electric traction, power transmission, central stations, and steam and electric power plants.

'88

H. RUSSELL SMITH is Chief Engineer of the Winslow Brothers Elevator Company, 757 Rookery Building, Chicago, Ill.

T. W. DEMAREST, who has been Assistant Engineer in the Motive Power Department of the Pennsylvania Lines, at Columbus, Ohio, has been appointed assistant to the Master Mechanic of the same system at Indianapolis, Ind.

'89

W. D. PALEN, who was Sales Agent for over three years, for the Link Belt Engineering Company, at Pittsburg, Pa., left this company about a year ago to take a similar position with the Philadelphia Textile Machinery Company, 2720 Hancock Street, Philadelphia, Pa., besides doing general engineering work in connection with the construction of dryers and other machinery manufactured by this company

J. R. ONDERDONK has been appointed Engineer of Tests, vice H. B. Hodges, resigned, of the Baltimore and Ohio Railroad Company, Mt. Clare, Baltimore, Md.

G. G. PLYER is Special Agent of the Lancashire Insurance Company, of Manchester, England, at Harrisburg, Pa.

'90.

H. S. LOUD is Superintendent of Plate Mill and Open Hearth Departments of the South Works, Illinois Steel Company, South Chicago, Ill.

HENRY M. BRINCKERHOFF is with the Metropolitan Elevated Railroad Company, 258 Franklin Street, Chicago, Ill.

E. E. HINKLE is Engineer and Contractor of Iron Work for Buildings, 518–520 West Twenty-second Street, New York City.

J. S. DEHART, JR., has been appointed Engineer of the Isbell Porter Company, 45 Bridge Street, Newark, N. J.

J. T. WESTCOTT, Manager and Treasurer of The Economical Gas Apparatus Construction Company, Suffolk House, Laurence Pountney Hill, London, England, has secured for his company the largest order ever given, at one time, to any company in England for Carburetted Water Gas Plant. It is to be of the Merrifield-Westcott-Pearson patent setting, of guaranteed 4,000,000 cubic feet daily capacity, or of a nominal capacity of 5,000,000 feet. This, Mr. Westcott believes to be equal to, if it does not exceed, any order ever placed in America. This company has recently completed the Blackburn plant, which has been a perfect success in every respect, is completing an installation for the Colchester Gas Company, Colchester, England, and is putting in a plant for the Peterborough Gas Company, Peterborough, Canada.

With regard to the Blackburn plant the *Journal of Gas Lighting, Water Supply, Etc.*, October 1, 1895, has this to say: "The contract was fully completed, we understand, a month prior to the stipulated time, and the guarantee given by the contractors has been amply covered by the every-day performance of the plant—a 'double event,' upon which the corporation and contractors are together to be congratulated. As the plant stands it is in all respects a workmanlike and creditable piece of gas engineering, complete to last particular; with nothing left to be adjusted or made good or to be in any way corrected. What this means in a new departure of this importance engineers do not need to be reminded."

JULIAN C. SMITH is Superintendent of the Metropolitan Railroad Company, Washington, D. C.

WILLIAM A. FIELD is General Night Superintendent of the South Works, Illinois Steel Company, South Chicago, Ill,

C. TEMPLE EMMET, of the firm of Emmet & Van Zelm, Attorneys and Counselors at Law, has established an office at 247 Main Street, New Rochelle, N. Y.

FRED. L. JOUBERT, of the firm of Payne & Joubert, Contracting Engineers, does a contracting engineering business for all classes of machinery required for the manufacture of sugar.

91

PAUL SPENCER is in the employ of the Stanley Electric Manufacturing Company, Pittsfield, Mass.

LOUIS B. WALKER is Manager of the New Jersey Metal Refining Works, Limited, Elizabeth, N. J.

M. C. JENKINS is Agent for the Coxe Iron Manufacturing Company, 143 Liberty Street, New York City.

'92

NICHOLAS S. HILL, JR., is the Engineer to the Electrical Subway Commission, 508 Equitable Building, Baltimore, Md.

P. L. WELLS, of the firm of Raders & Wells, is established in the American Tract Society Building, 150 Nassau Street, New York City.

'93

ORTON G. DALE was married to Miss Amy Slade, at the Prospect Street Presbyterian Church, Trenton, N. J., on Wednesday, February 12, 1896. Mrs. Dale is the daughter of the late Frederick J. Slade, of the New Jersey Steel and Iron Company.

WILLIAM B. AXFORD is the Consulting Engineer of the Harriman Wrought Iron Company, Jersey City, N. J.

A. E. MERKEL is with Hall & Fay, Patent Solicitors, 1015 Society for Savings Building, Cleveland, Ohio.

'94.

EDWARD P. BUFFET, JR., is Commercial Editor of the *American Machinist*, 256 Broadway, New York City, and is also a student at New York Law School, 120 Broadway, New York City.

FREDERIC J. ANGELL is in the draughting-room of the Solvay Process Company, Syracuse, N. Y.

Power OF FEBRUARY, 1896, contains an article on "The Flow of Steam in Pipes," by C. W. MacCord, Jr. Mr. MacCord also contributed a series of eight articles on Valve Gears to this journal which appeared successively in the issues from August, 1895, to March, 1896.

C. C. HARTPENCE is Assistant Engineer of the East River Gas Company, Long Island City, N. Y.

'95.

D. D. BARNUM has just completed a course in gas oil analyses with Dr. Stillman.

A. R. WILLIAMS is with the Wingfield Manufacturing Company, 248 Plymouth Street, Brooklyn, N. Y.

J. B. HAMILTON is draughting for the Baldwin Locomotive Works, Philadelphia, Pa.

H. C. ZIMMERMANN has accepted a position as draughtsman with Westinghouse, Church, Kerr & Co., New York City.

C. AUSTIN GREENIDGE is in the employ of the Mt. Morris Electric Light Company, Vandam and Greenwich Streets, New York City.

ALEXANDER K. HAMILTON is in the Testing Department of the Cambria Iron Company, Johnstown Pa.

B. C. BALL is the Chief Draughtsman and Designer for The Ball & Wood Company, Elizabeth, N. J.

ADAMS C. SUMMER has been spending the past few months in California engaged in fishing and hunting, and contemplates going to Japan. Upon his return he will probably go into the banking business in the West.

LATTIMORE CARTER is Inspector in the Department of Tests of the Southern Railway Company, 1300 Pennsylvania Avenue, Washington, D. C.

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VOL. XIII. JULY, 1896. NO. 3.

THE HELICAL CONVOLUTE, OR "SINGLE-CURVED SURFACE WITH A HELICAL DIRECTRIX."

BY PROF. C. W. MAC CORD.

The formation of a cylinder by rolling up a rectangular sheet of paper or metal, and of a cone by rolling up a sector of a circle, are familiar to all. Equally familiar is the fact that each of these surfaces is curved in one direction only, so that right lines can be drawn upon either—parallel to each other in the case of the cylinder, and meeting at the vertex in the case of the cone; and also the fact that these right lines will preserve the same relations when the sheets are again unrolled into planes. Consequently, no student of Descriptive Geometry finds any difficulty in conceiving the form, or in apprehending the properties, of any surface generated by a right line which, always intersecting a given curve, moves so as also either to remain always parallel to itself, or to pass always through a given point.

Now the cylinder and the cone, which are thus generated, have applications without number, while the other single-curved surface is very seldom met with; and this may be the reason why the student, not previously aware that there was any other, often does find it difficult to comprehend its nature and its peculiarities. This third surface of single curvature is generated by a right line, which moves so as always to remain *tangent* to a given line of double curvature. Of such lines one of the most common is the helix; and its use as the directrix of a surface belonging to the

class under consideration may be illustrated as follows: Cut a piece of paper into the form of a right-angled triangle, and roll it upon a cylinder, placing it so that its altitude shall coincide with a rectilinear element; when rolled up, the base of the triangle will coincide with the circumference of the base, and the hypothenuse will form a helix lying on the surface of the cylinder. In unwinding the paper, it is clear that the lower extremity of the hypothenuse will trace the involute of the base of the cylinder; while the hypothenuse itself will always be tangent to the helix, of which it is the prolongation, and its successive positions will be rectilinear elements of the surface in question. The helix may be regarded as made up of infinitely short right lines, of which any two consecutive ones must lie in the same plane, while no three can; the extension of any one of these forms a tangent to the curve, whence it follows that the consecutive elements of this surface intersect each other *two and two;* that is to say, element A intersects B, B intersects C, C intersects D, and so on, but A does not cut C, nor does B intersect D.

In studying this surface, a model like that represented in Fig. 1 will be found of material assistance. The helical directrix is traced upon the upright cylinder fixed in the base board; but since the rectilinear elements are tangent to the helix, the surface cannot extend within this cylinder, which might have been omitted altogether, and is introduced merely because it exhibits more clearly the form of the directrix, and throws the surface into stronger relief. The surface itself is formed of a sheet of white celluloid, which is admirably adapted for this purpose by reason of its lightness, toughness, polish. pliability, and the facility with which lines can be drawn upon it with properly prepared inks. The lower edge of this sheet fits into an inclined groove in the base board, of the form of the horizontal trace of the surface, which, as above indicated, is the involute of the base of the cylinder; for the sake of contrast, the base board is covered with a sheet of red celluloid,

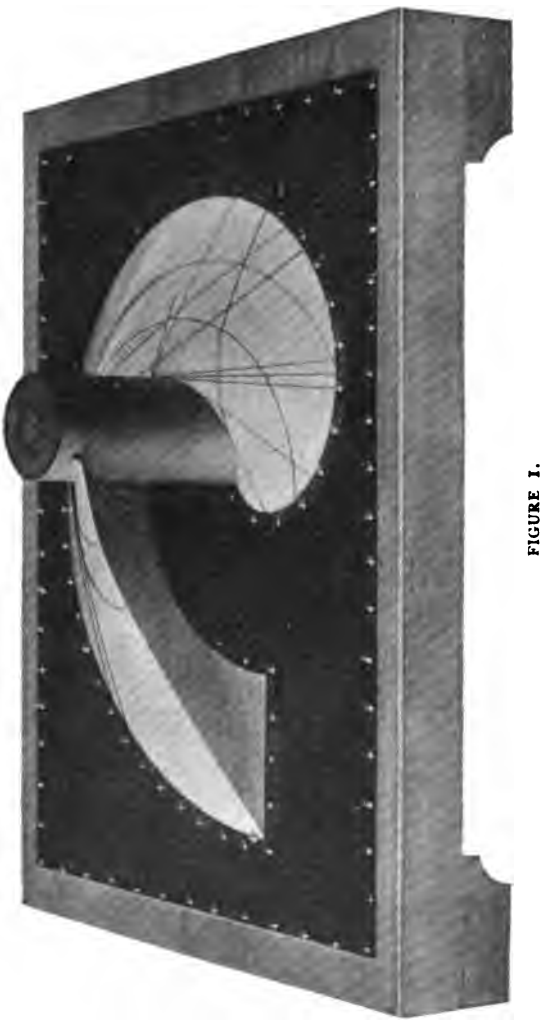


FIGURE I.

out of which that involute is cut. Thus the white sheet can be readily removed, unrolled into a plane, and replaced, thus illustrating the development of the surface; or, still better, by making a duplicate of it, the development can be directly compared with the surface itself. The model of course shows only a limited portion of the surface, which evidently might be extended indefinitely, winding round and round the central cylinder in convolutions like those of a sea-shell. This feature would in general characterize other surfaces of this class, all of which may therefore be appropriately called *convolutes*.

In this particular model, again, the surface is limited in a respect not yet pointed out; for the rectilinear generatrix terminates at the point of tangency to the helical directrix. It will now be readily seen that the tangent may be extended beyond this point, and that its prolongation will generate another portion of the surface, precisely similar to that shown in Fig. 1, but inverted. A model of the complete surface, thus composed of two nappes having the helical directrix as a common line, is represented in Fig. 2. This model was cut out of a "built up" block of wood, the two outer portions being of a light color, while the central one is darker, the three parts being carefully arranged as to thickness and position so as to exhibit a meridian section and a section by a plane tangent to the cylindrical core upon which the helical directrix lies.

This surface is obviously a helicoid of uniform pitch, and the model bears a close resemblance to the common V-threaded screw. Indeed, had it been made of metal, it could have been cut in the lathe with a straight-edged tool, but the high velocity required for working in wood made this impracticable in the present case, and the following method was adopted. Having determined the contour of a surface of revolution tangent to the helicoid, the axes of the two surfaces being perpendicular to each other, a cutter was made whose edge was a meridian section of that surface of revolution; this was mounted on the main spindle of a milling machine

FIGURE 2.

speeded up to a rate of 2,500 to 3,000 revolutions per minute, and the wooden blank being arranged upon the bed of the machine, the rotation, longitudinal travel, and cross-feed were effected by hand. A critical inspection of Fig. 2 will show that this model is not perfect, the generatrix not being absolutely straight in the portion near the axis, which perhaps is not to be wondered at, since the accurate determination of the form of the cutter by graphic operations, especially near the point, is a task of great difficulty, as is also that of grinding the cutter itself to the exact curvature required.

This particular surface is not only of interest as belonging to the family of screw threads, but is also one of the simplest of its class; the helix, having the same curvature throughout, will develop into a circle, and since the lengths of the tangents, which are the elements of the surface, remain unchanged, the base of the surface will develop into the involute of that circle.

Two other surfaces of the same class are shown in Fig. 3, which will no doubt appear to many as friends of their early days, each being merely a "whirligig" made by cutting through a circular disk along a spiral line drawn upon it, thus forming a long coiled strip, and this is hung upon a shouldered wire by a small hole at the pole of the spiral, which coincides with the center of the disk. Thus suspended, the strip by its own weight extends itself, as shown in the cut, into a surface which clearly is not warped, since it was originally plane and has undergone no distortion. The tangents to the plane spiral will become the rectilinear elements of the surface, remaining tangent to the double-curved line forming its directrix, which is not a helix, although in some respects analogous to one. These two surfaces, notwithstanding their lowly origin, are not by any means as simple as the one shown in the preceding figures; of which the skeptical would be convinced if confronted with the converse problem of determining two single-curved surfaces of this nature, such that the developments of their directrices should be in one case an Archimedean and in the other a logarithmic spiral.

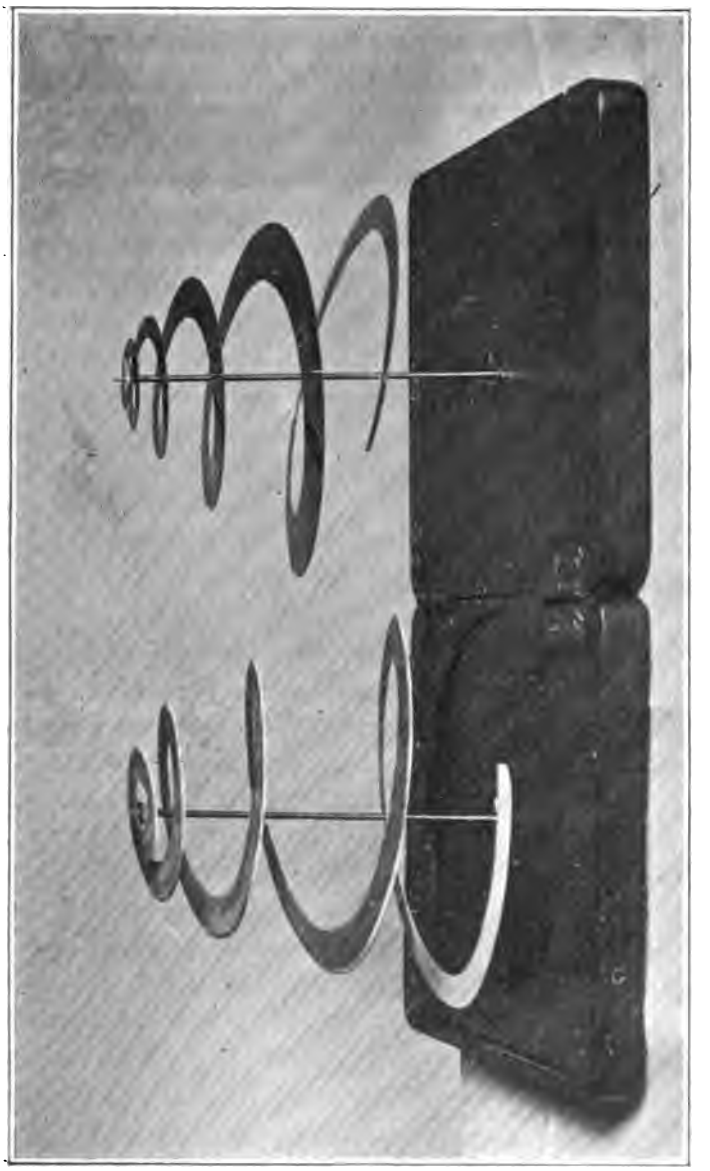


FIGURE 3.

without permission to make use of these developments in the process.

Now, in regard to the developable helicoid shown in Fig. 1, we quote the following from Church's Descriptive Geometry, Art. 134:

"It is a remarkable property of this surface, with a helical directrix, *that any plane passing through a rectilinear element is tangent to the surface*, at the point where the element intersects the directrix. For this plane will intersect the other elements, thus forming a curve. This curve will intersect the given element at the point where the element touches the directrix. The tangent to the curve at this point, and the element, both lie in the given plane; it is therefore tangent to the surface at the point. This plane does not, in general, contain the consecutive element, and is therefore not necessarily tangent all along the element. The projecting planes* of all the elements are tangent to the surface, and the cylinder formed by the projecting lines of the points of contact is therefore tangent to the surface."

In relation to the above it is to be observed that:

1. The element does not *intersect* the directrix, but is tangent to it; the first sentence seems therefore to contain a slip of the pen, which, however, leads to no misunderstanding and is not of material importance.

2. The curve cut from the surface is *tangent* to the element at their point of intersection, which is also a point of contrary flexure in the curve. The conclusion deduced is therefore at best a *non sequitur*, since it requires two non-concurrent tangents to determine a tangent plane. Professor Church distinctly recognizes this latter fact, as shown by the rule given in a previous article, (108), for drawing a plane tangent to a surface at a given point; it would appear, then, that he must have overlooked the fact that the element itself is the tangent to the curve mentioned.

* In Professor Church's diagrams the axis of the surface is vertical, as in the models illustrated.

3. Any two consecutive elements of the convolute determine an osculating plane of the directrix, and each element is the intersection of two successive positions of the osculating plane; therefore this surface may be generated by the motion of a plane, subject to the condition that it shall always be osculatory to a given line of double curvature. No plane can be tangent to a single-curved surface at any point, unless it coincides with some position of the generating plane; consequently a plane tangent to the convolute at any point must contain two consecutive elements, and be tangent to the surface all along an element; and obviously only *one* such plane can be passed through any point of the surface.

4. The "projecting planes" mentioned in the above quotation, are tangent to the cylinder upon which the directrix lies. And they do not satisfy the condition of tangency to the convolute, previously defined by Professor Church himself in Art. 108, as follows: "*A plane is tangent to a surface when it has at least one point in common with the surface, through which, if any intersecting plane be passed, the right line cut from the plane will be tangent to the line cut from the surface at the point.* This point is *the point of contact.*"

In the case under consideration, the point in question is the one at which the given projecting plane touches the directrix. As a test plane, let us take one perpendicular to the axis; this cuts from the cylinder a circle, from the convolute an involute of that circle; and from the projecting plane a right line, which is *normal* instead of tangent to the involute, at the given point.

5. Again quoting from Professor Church's Art. 108, "We have the following general rule for passing a plane tangent to any surface at a given point: *Draw any two lines of the surface intersecting at the point. Tangent to each of these, at the same point, draw a right line.* The plane of these two tangents *will be the required plane.*"

Applying this to the case in hand, draw through the given point the element of the convolute surface, and also the tangent to the involute above mentioned. This does determine correctly the

tangent plane, which will contain the consecutive element of the surface. But the tangent to the involute, and therefore the plane itself, will be normal to the projecting cylinder. This particular helicoid, then, instead of being *tangent* to the cylinder on which the directrix lies, as stated by Professor Church, is *normal* to it at every point of that helix.

It may be added that Professor Church uses the term helicoid in a very restricted sense, defining it as a surface generated by a right line revolving uniformly about an axis *which it intersects* at a constant angle, while at the same time advancing uniformly along it. This restriction seems not only needless, but unadvisable; the surface thus formed being but a special case of a whole class, generated by a right line, which remains at a fixed distance from the axis while revolving uniformly about it and advancing uniformly in a direction parallel to it, also making a constant angle with a plane perpendicular to the axis; all such surfaces are properly called helicoids of uniform pitch. The fixed distance from the axis will be the radius of the cylindrical well, or core, within which the surface cannot extend. Assuming this radius and the pitch of the helix described by its extremity, it is apparent that the inclination of the generatrix will materially affect the form of the surface. This generatrix cuts the elements of the cylinder at a constant angle; so, too, does the tangent to the helix just named; and these angles may or may not be the same. Let both angles on the same side of an element of the cylinder be acute; and through their common vertex pass a meridian plane and a transverse plane. Then if the angle between the generatrix and the element of the cylinder be greater, both sections of the surface will be looped curves, the vertices of the loops being respectively tangent to the element and the circle, cut from the cylinder. But if the other angle be the greater, those sections of the helicoid will be waved curves, the crests of the waves being tangent to the lines cut

from the cylinder; in either case if a plane tangent to the cylinder be passed through the generatrix, it will also cut from the helicoid a curve which intersects the generatrix, but is not tangent to it. And since the tangent to this curve at the point of intersection does not coincide with the generatrix, the plane in question is tangent to the helicoid at that point, and, moreover, is the only plane that can be. In both cases the helix traced on the inner cylinder is a true *gorge line* of the helicoid, which curves away from it so as always to be convex toward the cylinder, and is tangent to the latter all along that helix.

As the two angles mentioned approach equality, these loops and waves become smaller and more sharply curved at the vertex; at the limit, when the generatrix becomes tangent to the helix, there is neither loop nor wave, but each section consists of two branches, which form a *cusp* at the point where they meet the helix; and the common tangent to these four branches at that point is normal to the cylinder on which the helix lies. That helix is then not a gorge line, but an *edge of regression*, from which the helicoid recedes, not by curving away from it as in the other cases, but by being sharply reflected, or, as it were, doubled back upon itself. This particular convolute, then, stands on the dividing line between those oblique helicoids whose sections, meridian and transverse, are looped, and those of which these sections are waved; and among them it is unique in being of single curvature and developable, whereas the others are warped surfaces.

[illegible]

Indeed, in this case we might fairly say that the sources of light were different, the narrow edge being a different source from the flat face of the flame; but for each source the rule would hold good—i. e., a unit surface at 1 foot from the *face* of the flame would receive four times as much light as it would when drawn back to a distance of 2 feet from the same face, and the same is true as to a surface opposite the edge of the flame.

Such being the law, I will first point out its theoretical explanation.

Assume, to begin with, a luminous point. Now it would seem reasonable to take for granted that such a point would emit light equally in all directions, or at least that we could assign no reason why it should give out more light in one direction than in another. This being so, all the light emitted by this point would be evenly distributed over the inner surface of any sphere concentric with this point.

Suppose now, that we first consider a sphere having a radius of 1 foot and a corresponding surface of 12.566 square feet. To avoid complex figures I will assume in round numbers 12 square feet as representing the area of such a sphere. We may then say that $\frac{1}{12}$ of the entire light emitted by the luminous point will fall on each square foot of the surface of this sphere.

Now let us suppose that this hollow sphere is removed and another having a radius of 2 feet is substituted, thus doubling the distance between the luminous point and the surface of the sphere.

In this case again, the entire light from the point will be spread over the inner surface of the sphere, but by the familiar rule of geometry, we know that this surface will be four times as great as that of the sphere having a 1-foot radius, or (keeping the same assumed round number 12), will be 48 square feet, and consequently the amount of light falling on each square foot of this larger sphere will be $\frac{1}{48}$ of the total light emitted by the point, or one-quarter of the light received by each square foot of the smaller

sphere. This reasoning may be followed out as far as we like and will clearly develop as a necessary geometrical consequence of the assumption that the point emits light indifferently in all directions "the law of inverse squares" as stated already, where a luminous point is concerned.

Now we will turn to the case of a luminous surface, but first to make the transition easier let us suppose that we cut the supposed spheres in half by a vertical plane through the luminous center and consider only the hemispheres to the right of such plane. The same reasoning will apply with equal force to these hemispheres and the law of inverse squares will be equally deduced as a geometrical consequence.

Now then, let us assume a luminous surface of moderate area such as a gas flame or petroleum lamp with flat wick.

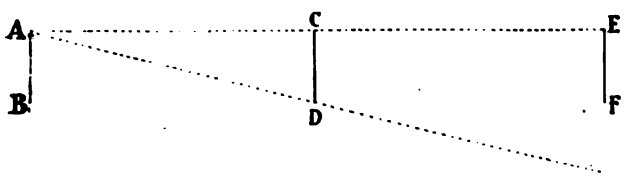


FIG. 1.

Let AB, Fig. 1, stand for two points at the outer edge of such a flame and let CD be a screen or surface 1 foot distant from said flame and EF the same screen or surface when moved away to the distance of two feet from the flame. Clearly the only rays from A which will reach the screen when at CD will be those included between the lines AC and AD as indicated in this section, or, in fact, within the solid angle of the cone or pyramid which has A for its apex and the area CD for its base. When, however, the screen is moved to EF, three-quarters of the light which fell on CD will pass beyond its edge because the base of the solid cone or pyramid included within the same angle will be four times as large at EF as at CD.

In other words, to catch all the rays from the point A that fell on CD the screen at EF would have to be twice as large in each direction or four times as great in area.

Manifestly the amount of light received from A by the same surface when removed to EF, would be one-fourth of that received when it was at CD.

Exactly the same would be true regarding rays from the point B, and therefore adding the light received from B to that received from A we must have four times as much on the screen at CD as on the same screen at EF.

We may, however, go on multiplying points between A and B as much as we like. The same conclusion would be reached as to

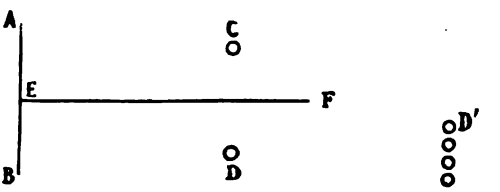


FIG. 2.

the light from each of them which would fall on a screen at CD and on the same screen or surface at EF, and thus as a mere example in addition, the sum of all the light from all the points constituting the surface between A and B which reached the same or an equal surface at CD would be four times as great as reached it at EF, which was at a double distance. This would fulfill the "law of the inverse squares."

So far for a theoretical discussion. I will now turn to a simple experimental demonstration.

Figure 2 represents a ground-plan of a very simple piece of apparatus. At AB we set up a light wooden frame on which is stretched a sheet of translucent paper or like screen. EF is an opaque screen of wood or the like at right angles to AB.

Now place two lighted candles at C and D, points equidistant from the screen AB. Then the half of the translucent screen between E and A will receive light only from the candle C, the opaque screen EF cutting off all light from the candle D and likewise with the half of the screen between E and B, so that we shall have the two halves of the translucent screen, the one receiving light only from candle C and the other only from candle D. Under these conditions, looking at these halves of the screen from the side AB, they will appear to be equally illuminated.

Now move back candle D to the distance of D′ twice as far as before from the screen. The half of the screen between E and B will now appear quite dark by comparison with the other half. Light another candle at the distance of D′ The half of the screen will still be much darker than the other and it will not be until we have four candles in all at D′ that the two halves of the screen will be equally bright.

This demonstrates that at a double distance only a quarter of the light from each candle reaches the screen, since it requires four candles at this distance to produce on the screen an illumination equal to that of one candle at the unit distance.

This experiment may be varied by taking two candles in place of four and moving them nearer to the screen until a balance of illumination is secured, when it will be found that the distances are as 1 to the square root of 2 (i. e.), 1.414, or in other words, such as the rule of the inverse squares calls for.

I do not mean to propose the above as the best or most accurate means of comparing lights, but take it for the purpose of illustration because it is probably the simplest and most direct, and one by which a multitude of combinations may be made, which, when repeated so as to eliminate by averaging, accidental sources of error, such as the irregular burning of the candles, will conclusively demonstrate the law of inverse squares.

Evidence of this sort might be indefinitely multiplied, there

being a whole science or art of photometry founded on the "law of inverse squares," and illustrating its accuracy in daily experience; but I can better employ time and space by now stating some of the more specious arguments which have been brought against the law of the inverse squares and pointing out their fallacies.

One of the most ingenious is the following: Suppose that AB, Fig. 3, is a luminous surface and CD is a screen, and that we consider the various rays starting from all parts of AB which meet at the point C on the screen, such as AC and BC, and as many as we choose to consider starting from points in the luminous surface between A and B and meeting at C. These will evidently be converging rays, and manifestly the law of inverse squares cannot apply here, because we have in this case convergence and concentration and not divergence and diffusion.

FIG. 3.

Now the radical fallacy here is in the assumption that a mathematical line can represent anything which actually exists in light emanation. Can anything in the way of light-motion which comes from a luminous point or surface be expressed by a uniform straight line? Clearly not, for from every point in a luminous surface light is passing outward in diverging directions through an entire hemisphere.

Thus let C, Fig. 4, be a point in the middle of a luminous surface; then light will emanate from this point in directions radiant from such point, such as are indicated by the radiant lines shown in the figure and countless others which might be drawn or imagined between them. If this was not so we could not see this point (as of course we do) when looking towards it from any direction.

This being so, it is clear that the smallest element into which we can divide the rays or emanations from the point cannot be correctly expressed by a uniform line, but would require for its correct expression a line growing thicker as it ran outward, so as to have cross-sections at successive distances, proportional to the squares of such distances, so that the aggregate of such lines would, by their cross-sections, fill the entire surfaces of successive concentric spheres.

In other words, to correctly express the emanating light rays, we cannot use uniform or mathematical lines, but must employ the spaces between such lines, radiantly drawn, to represent such rays. Thus in the figure neither Ca nor Cá can be properly used to represent an actual light ray, but rather the space between Ca and Cá.

FIG. 4.

If this was not so, then manifestly no matter how closely the radiations represented by uniform lines were packed together near the luminous point, it would only be a question of distance when they would be separated by dark spaces, and a screen placed to receive them would look like a piece of black calico with white polka dots scattered over it.

Realizing then that every ray of light must in fact be such an expanding pencil whose cross-section will increase with the square of its distance from the source, and whose intensity for unit area will decrease in the same proportion, it will be manifest that even in the case of the converging rays shown in Fig. 3, the amount of light falling on any element of surface C will be less and less as the

surface recedes from the source of light in proportion to the square of the distance; or in other words, its amount will be in accordance with the law of the inverse squares.

It will be seen on further reflection that the whole question resolves itself into this: Is light truly a radiant action or form of energy proceeding in all cases in radiant lines from each luminous point whether the same stands alone or forms part of a luminous surface? If this is true, the law of inverse squares follows as a necessary consequence, as certain as the numerical relations between the diameters and circumferences of circles or the radii surfaces and solid contents of spheres.

That light *does* proceed in radiant pencils from luminous points whether the same be alone or constitute part of a surface is a matter of common observation, because we all know that we can see a point in a luminous surface as well from one direction as another, which, of course, would not be true if the rays went only or mainly in a direction perpendicular to the surface.

I, of course, exclude observations where there is absorption in one direction more than in another, or where there are any other modifying actions, unless allowance is made for them. Among these are of course included all cases in which, from the peculiar structure of the source of light, conspicuously electric arc lamps and some incandescent lamps, more light-surface is available towards one direction than towards another. In such cases as these we can trust the law of inverse squares in measuring the light given off in each direction, but must make numerous measurements in different directions and add or average these when we desire to determine the total or the average illuminating effect.

Of one thing we may rest assured, namely, that radiation—i. e., emanation in radiating pencils from every luminous point—is the only way in which light passes away from a luminous source.

If any one should discover a source of light from which rays proceeded in some other way, he will have made a great discovery,

and the sort of light he so discovers will be as wonderful as the Roentgen rays, and will obey some other law than that of the inverse squares. But as long as we are dealing only with that ordinary sort of light which is now generally known and familiar, we may rely upon it for an implicit obedience to the law of the inverse squares. We have examples of forces or energies which are not radiant. Thus the lines of magnetic force between the poles of a horseshoe magnet are substantially parallel, and the cathode rays as shown by Professor Crookes are in some cases parallel and in others convergent, being emitted in directions normal to the surface from which they proceed.

For such emanations there is of course no law of inverse squares. But this, as Kipling says, is another story.

Again we may, by the use of lenses and mirrors, take light rays coming in divergent pencils, such as I have described, and render them parallel or convergent, or give them any relation of direction we please by the use of lenses and mirrors, and when they are so radically modified the law of inverse squares will of course fail to apply. But this, too, is another story, and no one is so foolish as to propose to apply a photometer to the measurement of a light whose rays have been rendered parallel by a lens or have been radically changed by like treatment; although it is true that some have referred to rays which by a lens or other unexplained means had been brought into an abnormal state, as if this had something to do with the law of the inverse square or the use of the ordinary photometer.

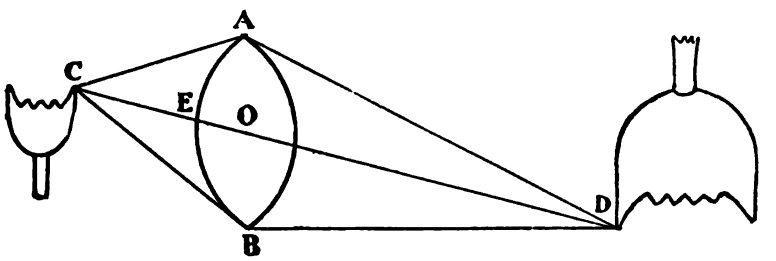
Speaking of a lens reminds me that the ordinary action of a lens in forming an image is a capital demonstration of the statements I have made about the independent radiation of light pencils from each point in a luminous surface.

Thus, as everyone knows or can prove for himself with a gas flame, a sheet of white paper, and a lens, such even as a spectacle lens for long-sighted eyes, if the lens is held at the proper distance,

found by trial between the flame and the paper, an inverted image of the former will be produced on the latter.

This is simply because each point in the luminous surface of the flame throws out independent pencils or cones of light which are by the lens turned about so as to meet at corresponding points on the paper or screen.

Thus let AB represent a lens and C a point in a gas flame, then the rays or emanations from this point falling on the lens at AE and B, and at points between, will be so refracted or bent as



to meet at D, and there produce the corresponding point of the image.

The same is true in reference to every other point in the flame surface and the corresponding point of the image, which is in fact made up of a countless number of points, each produced by the light from a corresponding point in the flame. If, however, the light from the flame came in parallel directions upon the lens, it would all be collected in one point (the principal focus of the lens), and no image would be formed.

A ROTARY FIELD MOTOR FOR LECTURE PURPOSES.

BY ALBERT F. GANZ, M. E.,
Instructor in Applied Electricity, Stevens Institute.

DESCRIPTION OF MOTOR.

A general view of this motor, which was briefly mentioned in the last number of the INDICATOR, is shown in Fig. 1 It was constructed in the electrical laboratory of the Institute, with a view of obtaining a simple piece of apparatus for illustrating the principles of rotating magnetic fields, as embodied in commercial induction motors. The model has proved so generally useful that a brief description of it, together with a simple explanation of the theory involved, may be of interest.*

The model consists essentially of a laminated ring electromagnet of square cross-section, having a mean diameter of 27.5 centimeters and sectional area of 18.4 square centimeters. This ring is divided into 12 equal parts by radial flanges, and each part is wound with 140 turns of No. 14 B & S wire; the ends of each coil are brought to separate binding posts on the base of the model. By this arrangement the coils can be grouped in any manner desired.

In the center of this ring, and just below it, is a brass disc free to rotate. Figure 2 shows a cross-section of the bearing; it consists of a vertical steel shaft (A) running in a brass bearing (B), together with a pair of steel discs (C) separated by steel balls placed in suitable grooves and forming a horizontal ball bearing. The brass disc (D) is a sort of turn-table upon which the masses of metal, armatures, or rotors generally, with which we wish to experiment, may be laid or suitably fastened. The weight of the rotating mass is thus supported by the steel balls, reducing friction to a minimum.

* For a complete analytical treatment of the subject see "Polyphase Electric Currents," by S. P. Thompson.

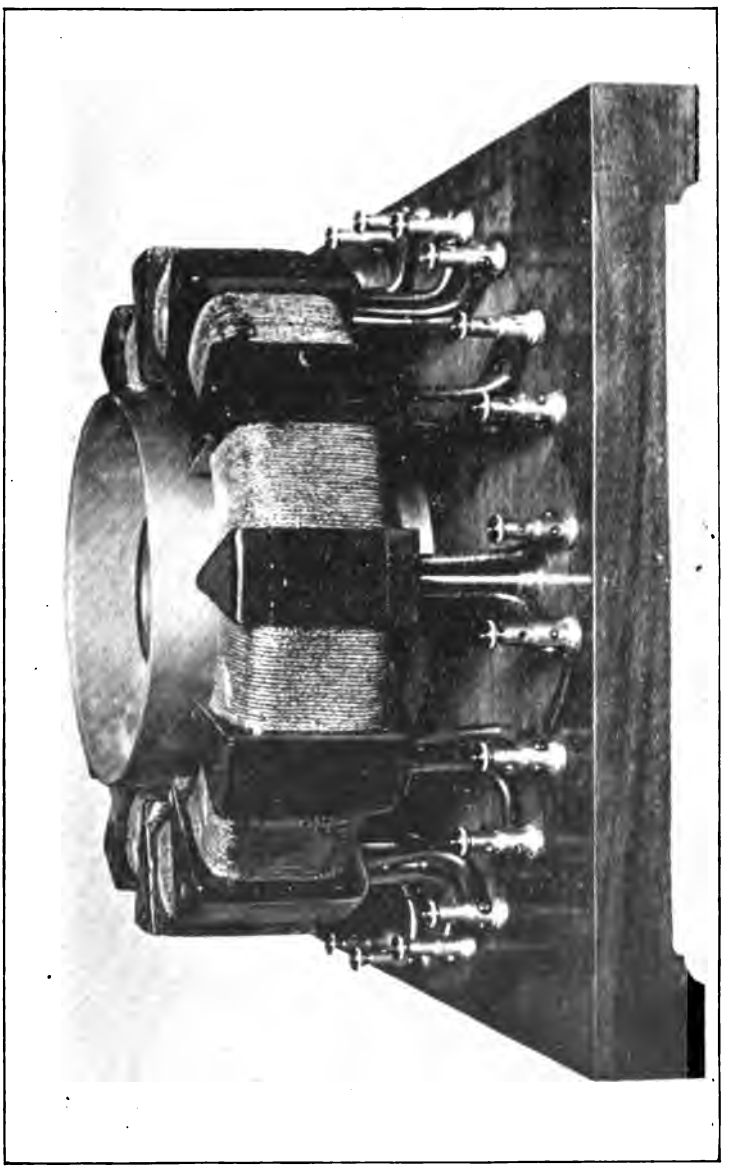


FIG. 1.

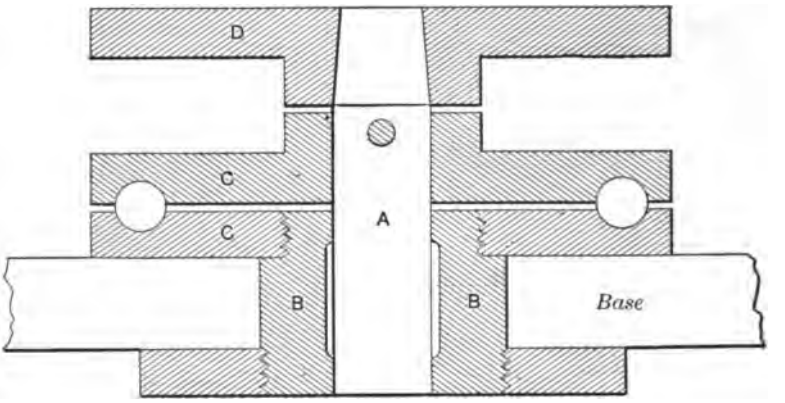


FIG. 2.

PRODUCTION OF ROTATING FIELDS.

The simplest rotating field is produced by revolving an ordinary horseshoe magnet about an axis passing midway between the poles. By taking a number of magnets, with their poles alternately N and S, we can produce a multipolar rotating field. If a disc of copper or iron is pivoted in the axis of rotation and placed near such a magnet, it will be dragged around with the rotating field, due to the eddie currents induced in the disc. Such rotations have long been known under the name of Arago's rotations.

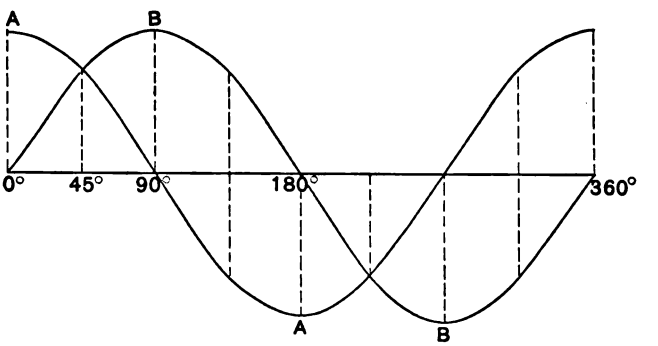


FIG. 3.

Such traveling poles can also be produced by the proper combination of alternating currents, differing from each other in phase. At least two such currents are necessary, in which particular case the phase difference should be 90 degrees. Such are the ordinary two-phase currents, graphically represented in Fig. 3. One method of connecting the coils for two-phase currents is shown in the diagram, Fig. 4.

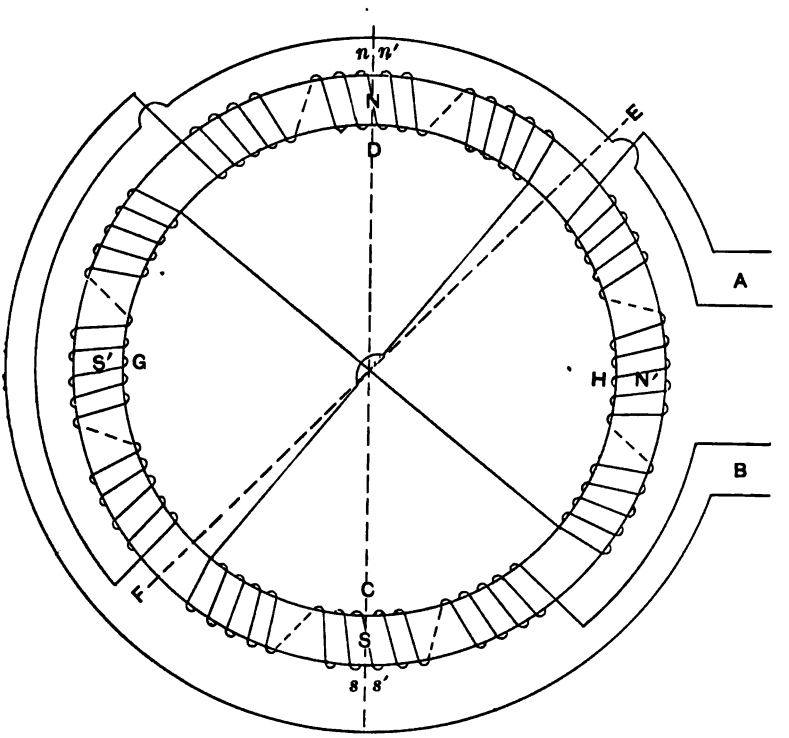


FIG. 4.

At one particular instant, marked 0° in Fig. 3, the current in A is a maximum, and that in B zero, so that the resultant magnetization is that due to A alone. If the ring were cut in two across a diameter C–D, coils G, on one half of the ring, would produce the

poles n and s; coils H, on the other half, the poles n' and s'. When both coils are active, as they really are, the ring can be joined again and the resulting poles will be at N and S. The general direction of the lines of force at this instant is shown in Fig. 5.

One quarter-period later, marked 90° in Fig. 3, the current in A is zero and that in B a maximum, so that the magnetization at this instant is that due to B alone, bringing the resultant poles to N′ and S′. At a time half-way between these two, marked 45° in Fig. 3, both set of coils are equally active. G and H tend to produce poles at N and S, while C and D such at N′ and S′. The resultant poles will therefore be midway between or at E and F. The same reasoning would show that at any intermediate time the resultant poles would be at corresponding intermediate points.

One half-period after the first instant considered, marked 180° in Fig. 3, the current in B is zero and that in A has reversed and is again a maximum; the poles will therefore be N and S reversed. Another quarter-period later the poles are N′ and S′ reversed, and at the end of a complete period the poles have made one complete revolution.

In fact, if the two currents are of equal period and amplitude and differ by exactly quarter of a period, the resultant field has a constant value, and rotates with a uniform angular velocity. Three equal currents, differing by 120 degrees, applied to three coils placed symmetrically will also produce a resultant constant rotating field.* Or, in general, any number of equal currents of as many phases may be applied to as many symmetrical coils with the same result. A pivoted magnet placed inside of this ring would be dragged around in synchronism with the revolving poles, and would make a synchronous multiphase motor.

* For an analytical proof of this see "Polyphase Electric Currents," page 63.

The paths of the lines of force for one instant are shown in Fig. 5; they are seen to stream across the interior of the ring, and, as explained above, this system of magnetic lines rotates about the axis of the ring at a rate corresponding to the frequency of the alternating current.

Suppose now that we place a mass of metal inside of the ring; this is usually known as the rotor; the lines of force, rotating about the axis, evidently cut this mass of metal and set up in it electromotive forces, and these in turn produce currents. The general

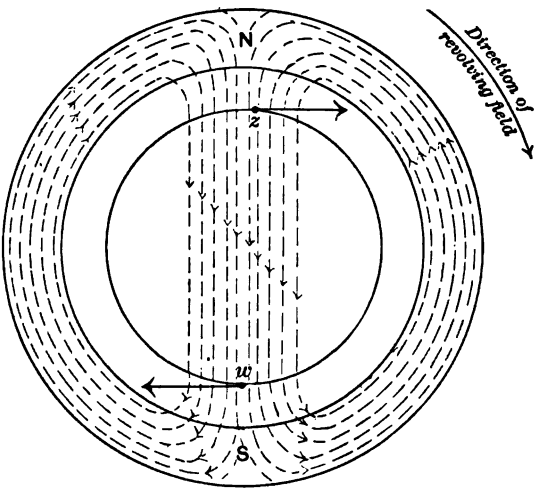


FIG. 5.

direction of these currents is found by applying Fleming's three-finger rule, using the right hand; it must be borne in mind that we have to assume the rotor to revolve and the lines to remain fixed when applying the rule. The general direction of currents at *z* will be towards the reader and at *w* away from the reader, perpendicular to the plane of the paper; now these currents are in a magnetic field, and consequently the rotor, carrying the currents, experiences forces tending to move it. To find the direction of

these forces, we apply Fleming's three-finger rule for motors, using the left hand; it will be found that these forces at *z* and *w* are in opposite directions, and produce a couple in the direction of the rotating magnetic field. If our rotor is pivoted it will be set into rotation in the direction of the revolving field. Very good results were obtained with an ordinary iron pulley, shown in the illustration, Fig. 1.

The magnitude of the couple varies as the square of the number of lines of force; for, if this number is doubled, the current induced in the metal is also doubled, so that the force between the two is quadrupled. For a given magnetizing current, the flux depends directly on the goodness of the magnetic circuit; and since the space inside of the ring always forms part of this circuit, the flux will be increased by introducing iron into this space.

The currents induced depend upon the rate of cutting of the lines of force; this rate is greatest when the rotor is fixed, and decreases as it begins to revolve, finally becoming zero if its speed of rotation should become that of the magnetic field. The difference between the angular velocities of field and rotor is called, by S. P. Thompson, the slip; the cutting of lines, and therefore the induced currents, are due to this slip; and since the rotation is produced by these induced currents, there must always be some slip. That is, such a motor cannot run in synchronism with the rotating field.

Instead of producing simply two traveling poles, we can so connect our coils as to produce a number of such poles. The diagram, Fig. 6, shows the connections for producing six traveling poles by means of two-phase currents. The capitals N and S indicate the positions of the poles at one instant when the current in B is a maximum; one quarter-period later these poles have shifted to the positions indicated by the small letters *n* and *s*—that is, through 30 degrees. We thus have a multipolar rotating field, the number of rotations of the field being equal to one-third the [illegible] of the alternating-current supply. This method of con-

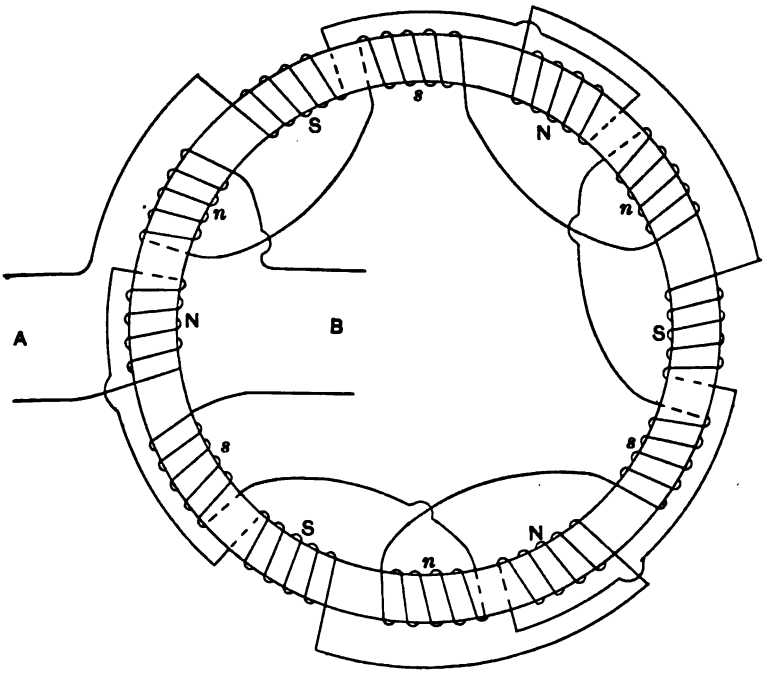


FIG. 6.

necting therefore affords a means of obtaining slow speeds. By increasing the number of poles, we decrease the number of revolutions of the rotor in the inverse ratio.

CLOSED COIL ARMATURES.

So far we have only spoken of masses of metal to be used as rotors; the general direction of induced currents in such masses of metal will be as has been shown above. But some of the currents will not flow in the proper direction to help produce motion, and such currents will be wasted. To avoid this waste we must restrict the induced currents to flow in directions in which they can do useful work, which direction is parallel to the axis. This is accom-

plished by winding conductors upon a core and so connecting these conductors that the current flowing upward near one pole returns downward near an opposite pole. In the case of the bi-polar type this would be across a diameter; in the six-pole winding mentioned, the span would be 60 degrees. A number of closed circuits would thus be established in which the induced currents would flow in directions proper for producing rotation. Another very common form of connecting these conductors together is that known as the squirrel-cage construction. This consists in connecting together all the conductors on each end by means of a ring. Such an armature will run in any rotary field. For our model we constructed a squirrel-cage armature by making a cylinder of sheet copper and cutting into this a number of slots parallel to the axis of the cylinder.

The core is ordinarily made of soft iron, laminated in a direction perpendicular to the axis. At the moment of starting, the induced currents are very large; the effect of this is to partially neutralize the magnetizing effect of the field coils, which will then draw very large currents from the supply. To avoid this a starting resistance is introduced.

Since the secondary circuits have inductance, there is always a lag between the secondary currents and induced electromotive forces, and consequently also between the primary and secondary currents. This is an important matter in the design of these motors.

Several other uses of the model may be mentioned as matters of curiosity. The field magnet by itself can be used as a static transformer, with a variety of ratios. S. P. Thompson's method of phase transformation can also be illustrated; for this purpose all coils are connected in series. If two-phase currents are supplied to four symmetrical points on this series, three-phase currents can be drawn from three symmetrical points on the series; or *vice versa*. This is a very striking experiment.

Besides the few methods of connection for producing rotary fields, already mentioned, a number of other methods may be used, some of which will readily suggest themselves.

REVERSING INDUCTION MOTORS.

It has been shown that the rotor follows the direction of rotation of the revolving field. So to reverse the direction of the rotor we must reverse the rotation of the magnetic field. In the two-phase system this is effected by interchanging the wires of one circuit, so that, if continuous currents were used, the direction of the current would be reversed in one set of coils. In the three-phase system, using three wires, the reversal is effected by interchanging any two of the three wires.

MECHANICAL INTEGRATORS.*

BY PROF. J. BURKITT WEBB.

(*Concluded.*)

POLAR TRACTRIX.

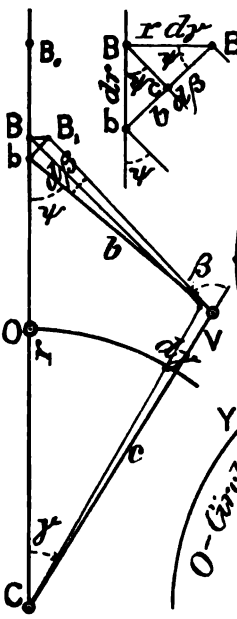


FIGURE 48.

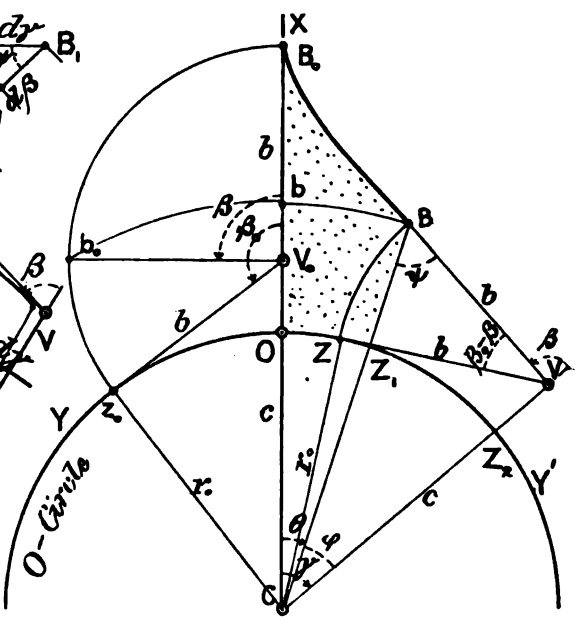


FIGURE 49.

* The previous portions of this article appeared in the January, 1895, April, 1895, and April, 1896, numbers of the INDICATOR.

VERIFICATION OF THE FORMULA.

The formula may be verified by obtaining it from Fig. 49 without the use of the infinitesimal calculus.

Passing the combined Wheel and Stylus around the boundary $B_0\,B\,Z\,Z_0\,B_0$, the area thereof is obtained as

$$Area\ B_0\,B\,Z\,Z_0 = bR = b^2\beta,$$

b being now the length of the Measuring-Bar. The Reading R is evidently due to a zero motion of the Wheel on $B_0\,B$, a minus motion on $B\,Z$, a zero motion on $Z\,Z_0$ and a plus motion on $Z_0\,B_0$; it is therefore due to the difference of the arcs $Z_0\,B_0$ and $Z\,B$, or to $b_0\,B_0$. This gives $R = b\,\beta$.

The required area is

$$Area\ B_0B\,Z_1O = B_0B\,Z\,Z_0 + BVZ_2Z - B_0V_0O\,Z_0b_0 + Z_1Z_2C - BVC.$$

The first term of this expression has been obtained by the planimeter. The second term minus the third is seen in the figure to be equal to $-\frac{1}{2}b^2\,\beta$, because $b_0\,Z_0\,C\,V_0$ and $B\,Z\,C\,V$ are the same figure, leaving $b_0\,V_0\,B_0$ for the difference. The fourth term equals $\frac{1}{2}r_0^2\,\phi = \frac{1}{2}(c^2 - b^2)\,\phi$ and the fifth equals $-\frac{1}{2}cb\wedge\beta$. Therefore, with $\wedge$, $\frown$, $\lrcorner$, for sine, cosine, tangent, as before, the above value of the area becomes

$$Area\ B_0B\,Z_1O = \tfrac{1}{2}b^2\beta - \tfrac{1}{2}cb\wedge\beta + \tfrac{1}{2}(c^2 - b^2)\,\phi.$$

To reduce this expression to that obtained by integration, notice that, by trigonometry, the value of the half-tangent is

$$\lrcorner\tfrac{1}{2}(\psi - \phi) = \frac{c-b}{c+b}\lrcorner\tfrac{1}{2}(\psi + \phi = \beta)$$

whence

$$\phi = \tfrac{1}{2}(\psi + \phi) - \tfrac{1}{2}(\psi - \phi)$$
$$= \tfrac{1}{2}\beta - \lrcorner^{-1}\frac{c-b}{c+b}\lrcorner\tfrac{1}{2}\beta,$$

substituting and reducing

$$B_0B\,Z_1O = \frac{c^2+b^2}{2}\cdot\tfrac{1}{2}\beta - \tfrac{1}{2}cb\wedge\beta - \frac{c^2-b^2}{2}\lrcorner^{-1}\frac{c-b}{c+b}\lrcorner\tfrac{1}{2}\beta.$$

This way of arriving at the formula makes clear the meaning of its terms and shows them to be as simple as the case allows. The expression containing ϕ is, moreover, the most serviceable for this discussion.

DISCUSSION OF THE FORMULA.

Considering the Tractrix as continuously generated in the manner already described by the continuous increase of β, it is seen that for the first form, where $c > b$, ϕ, γ, and θ oscillate, while β increases steadily, thus,

$\beta = 0$	$\phi = 0$	$\gamma = 0$	$\theta = 0$
$= \beta_0$	$= (\beta_0 - \frac{1}{2}\pi)$	$= \infty$	$= \infty$
$= \pi$	$= 0$	$= 0$	$= 0$
$= 2\pi - \beta_0$	$= -(\beta_0 - \frac{1}{2}\pi)$	$= -\infty$	$= -\infty$
$= 2\pi$	$= 0$	$= 0$	$= 0$

and so on through each 2π period. The expression depends, therefore, upon the first term alone for whole and half periods, so that the area of the whole Tractrix of the first form (see Fig. 43) is found by putting $\beta = 2\pi$, which gives

$$Area\ B_0\ B_1 \infty B_0' \infty I\ B_0 = \pi b^2.$$

This expression may be readily verified from Fig. 43, for let the area of the circle $B_0\ B_2\ B_0'\ B_2'\ B_0$ be added to that of the Tractrix, and let the Stylus be passed first around that curve from B_0 through B_1 to B_0 and then around the circle, from B_0 through B_2 to B_0, then the area added is πb^2, and the whole Reading multiplied by b equals $2\pi b^2$, the difference being πb^2, as above obtained. To avoid the circular area lying over that of the Tractrix, the right-hand half of the latter and left-hand half of the former may be combined and the half-area $\frac{1}{2}\pi b^2$ obtained. It is to be noticed here that the addition of the circle is a means of *returning* β to its initial value.

For the area of an outer branch put $\beta = \beta_0$, whence $\phi = \beta_0 - \frac{1}{2}\pi$, then between the curve and the o-Circle the

$$Area\ B_0\ B_1 \infty B_2\ O\ B_0 = \tfrac{1}{2}b^2\beta_0 - \tfrac{1}{2}cb \wedge \beta_0 + \tfrac{1}{2}(c^2 - b^2)(\beta_0 - \tfrac{1}{2}\pi)$$
$$= \tfrac{1}{2}[c^2\beta_0 - br_0 - \tfrac{1}{2}\pi(c^2 - b^2)]$$

and for an inner branch, between $\beta = \beta_0$ and π and $\phi = \beta_0 - \frac{1}{2}\pi$ and o,

$$Area\ B_0'\ O\ B_2 \infty B_0' = \tfrac{1}{2}[-c^2\beta_0 + br_0 + \tfrac{1}{2}\pi(c^2 + b^2)]$$

the sum of the two being evidently $\frac{1}{2}\pi b^2$.

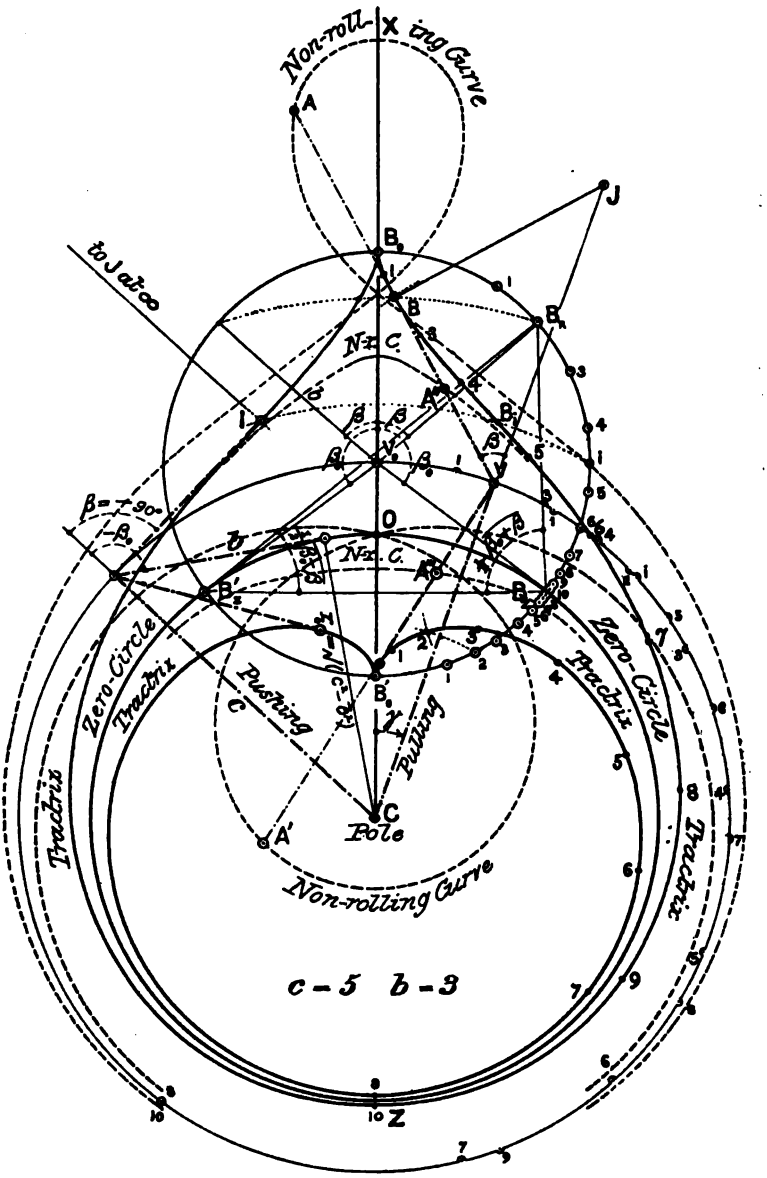


FIGURE 43. POLAR TRACTRIX.

Inasmuch as c does not appear in the value of this area, it follows that for all half Tractrices of the first form, having the same parameter b of size, the area is the same, and therefore the same as that of the Common Tractrix, for which $c = \infty$, and of which the four outer and inner branches have the same area, $\frac{1}{4}\pi b^2$. Notice that if c be put equal to infinity in the equation, to get the area of one branch of the Common Tractrix, $\beta_0 - \frac{1}{2}\pi = \phi$ must not be placed equal to zero, because $c^2\phi = c \,.\, c\phi = cb$, and ϕ is an infinitesimal of the first order. With $c = b$ the o-Circle and the inner branch disappear and the outer branch contains the whole area, $\frac{1}{2}\pi b^2 = \frac{1}{2}\pi c^2$.

Near the o-Circle the area lies in many layers, one upon the other, so to speak, on account of the many convolutions of the spiral.

WIDTH OF THE TRACTRIX.

The Exponential Equation of the Polar Tractrix is

$$e^{-\sqrt{-1}\beta_0 \gamma} = \pm \frac{\Lambda\frac{1}{2}(\beta_0 + \beta)}{\Lambda\frac{1}{2}(\beta_0 - \beta)}$$

For a fixed value of γ the left-hand, and consequently the right-hand member of this equation, become constant; the latter member has, however, two values, corresponding with the outer and inner branches, which values must therefore be equal to each other, thus:

$$\frac{\Lambda\frac{1}{2}(\beta_0 + \beta)}{\Lambda\frac{1}{2}(\beta_0 - \beta)} = -\frac{\Lambda\frac{1}{2}(\beta_0 + \beta')}{\Lambda\frac{1}{2}(\beta_0 - \beta')}$$

where β' is used for the inner branch.

In Fig. 50 these angles are shown, and, as the chord of any angle equals twice the sine of half the angle, the chords shown in the figure may be substituted for the half angles in the last equation, thus:

$$\frac{Chord\ \mathrm{B\,Z'}}{Chord\ \mathrm{B\,Z}} = \frac{Chord\ \mathrm{B'\,Z'}}{Chord\ \mathrm{B'\,Z}}$$

In the four triangles C B Z, etc., C B $= r$; C B' $= r'$; C Z $= r_0 = \sqrt{r\,r'}$; etc.; and, if the chords B Z', etc., be expressed in terms

of the other two sides and included angle of their triangles, there results:

$$B Z'^2 = r^2 + r_0^2 - 2 r r_0 \nearrow \phi_0' = r (r + r' - 2\sqrt{r r'} \nearrow \phi_0')$$
$$B Z^2 = r^2 + r_0^2 - 2 r r_0 \nearrow \phi_0 = r (r + r' - 2\sqrt{r r'} \nearrow \phi_0)$$
$$B' Z'^2 = r'^2 + r_0^2 - 2 r' r_0 \nearrow \phi_0' = r' (r + r' - 2\sqrt{r r'} \nearrow \phi_0')$$
$$B' Z^2 = r'^2 + r_0^2 - 2 r' r_0 \nearrow \phi_0 = r' (r + r' - 2\sqrt{r r'} \nearrow \phi_0)$$

from which it is evident that the relation between the four chords, just deduced from the Exponential Equation of the Polar Tractrix, holds also in Fig. 50, so that

For any particular value of γ the points B *and* B' *on the outer and inner branches lie in a straight line* C B' B, *and, consequently, θ has but one value for each value of γ.*

The line B B' is the *width* of the Tractrix, being perpendicular to the Zero-Circle, and being part of the radius generating the area between the two branches of the curve. Its length is

$$B B' = 2b \wedge \tfrac{1}{2} (\beta' - \beta).$$

MORPHOLOGY OF THE TRACTRIX.

As already stated, the case $c < b$ was passed over in the original treatment of the Polar Tractrix as having no bearing upon the planimeter as ordinarily constructed, nor was any formula for area developed. The discussion of this case, however, is quite as interesting as the other.

As c diminishes from ∞ to b plus an infinitesimal, the Tractrix curls its tails up, so to speak, the asymptotic Y-axis with the infinite branches curling up into the o-Circle, which grows smaller and smaller as c diminishes. Considering now a number of sufficiently large fixed values for γ, including its infinite value for the full length of a branch, it is evident that the lengths of the branch corresponding to those values, and therefore including the complete length, must diminish with the o-Circle, and as the total area πb_2 is independent of c as long as $c > b$, the width of the Tractrix increases as c diminishes.

When c becomes less than b the length of a branch of the curve becomes finite, the inner branches disappearing and the

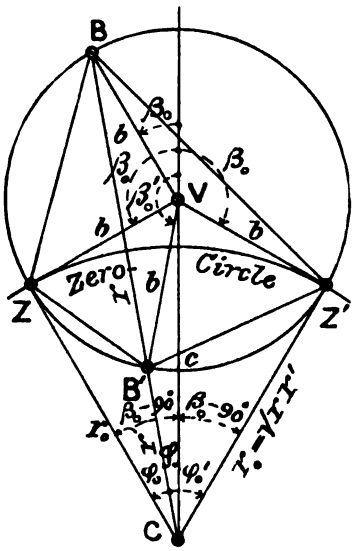


FIGURE 50.

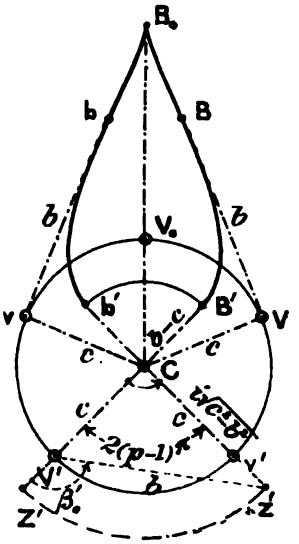


FIGURE 51.

outer repeating themselves, in leaf form, as already shown. The tail has now been, so to speak, absorbed, and the Tractrix appears in a new and more highly developed form.

AREA OF THE SECOND FORM.

Returning to the formula,

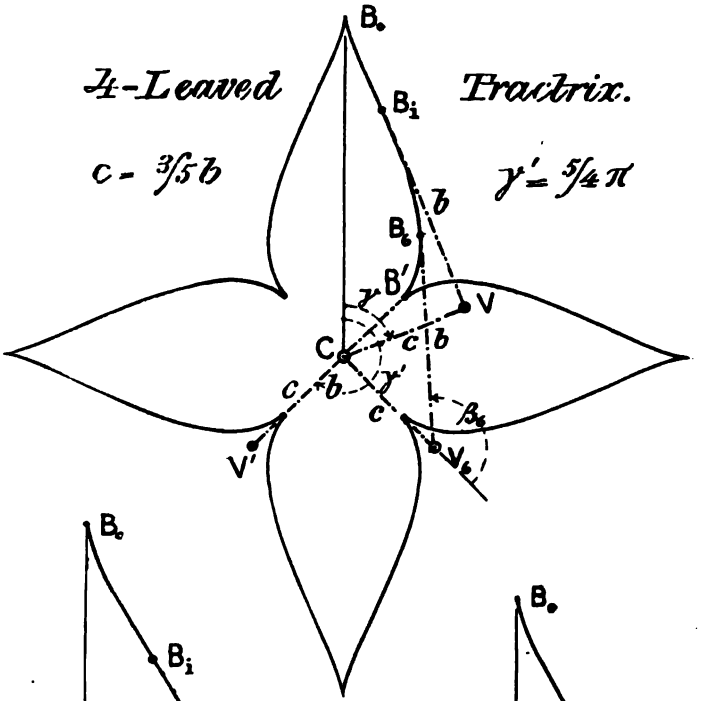
$$A = \tfrac{1}{2}b^2\beta - \tfrac{1}{2}cb\sin\beta + \tfrac{1}{2}(c^2 - b^2)\phi,$$

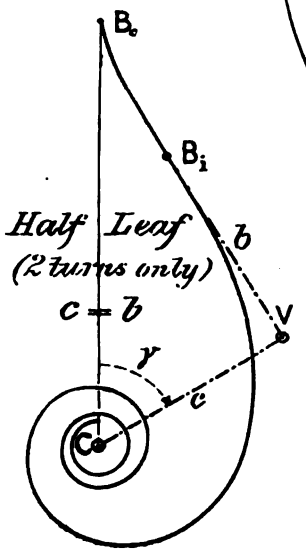
it is to be noticed that when $c > b$, or the parameter of form $c_1 > 1$, ϕ, γ and θ simply oscillate, as already shown, but when c, by an infinitesimal decrease, becomes less than b, this oscillation changes into a continuous revolution. The half period of ϕ is then π, the same as β, while that of γ and θ is $p\pi$, as already shown. This change not only prevents the disappearance of the ϕ term from the formula for the area of a half leaf, but causes the other terms to vanish, inasmuch as the half-period values of β and ϕ are both 2π. This gives for half the area of the leaf, Figs. 51, 47, etc.

Area of a half leaf $= \tfrac{1}{2}\pi c^2$.

What the inner boundary of this area is, now that the o-Circle

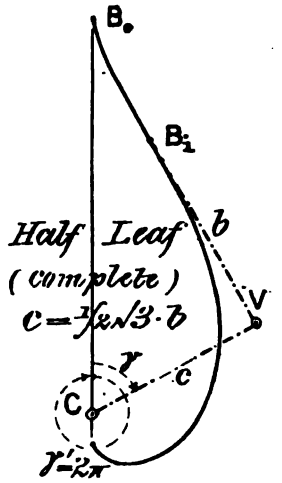
FIGURE 47. POLAR TRACTRIX.





0-Leaved Tractrix

FIGURE 45.



1-Leaved Tractrix.

FIGURE 46.

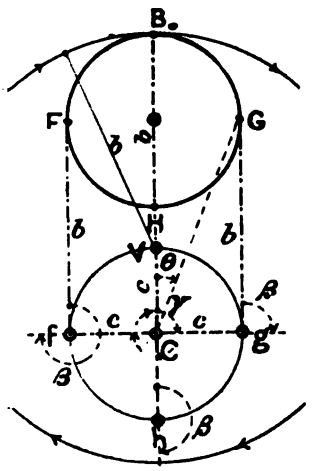


FIGURE 52.

has disappeared, is not at once clear but will become so upon verifying the formula by a process similar to that already employed.

PECULIAR CASE.

Before verifying the formula a case will be examined similar to the "PECULIAR CASE" previously discussed and involving an *Imaginary Zero-Circle.*

Figure 52 shows a circle B_0GHF whose area is to be measured. Starting with the instrument in the position CVB_0, the circuit $B_0\,G\,H\,F\,B_0$ is made with the Wheel, while the Hinge makes the similar circuit $V\,g\,h\,F\,V$, the Measuring-Bar remaining always parallel to VB_0. When the Wheel arrives back at B_0 and θ is again o, hold the Hinge V still and revolve the Measuring-Bar one turn about V in the direction of the arrows; this will return β from from 2π to its initial value and advance θ from o to 2π, so that the area of the o-Circle must be added once.

The Reading will then be due to the large circle alone, or

$$K = 2\pi b.$$

Multiplying by b and adding the area of the o-Circle, which has the same value as produced for the first form of the Tractrix, viz.:

$$\textit{Area of o-Circle} = \pi r_0^2 = \pi\,(c^2 - b^2),$$

there results for the area of the crossed-boundary figure $B_0GHFB_0 \ldots . B_0$,

$$A = 2\pi b^2 + \pi\,(c^2 - b^2) = \pi\,(b^2 + c^2),$$

which is evidently the sum of the two circular areas included by the crossed-boundary.

VERIFICATION OF THE FORMULA.

If the Wheel be moved over the contour of the leaf, Fig. 51, from b′ through b, B_0, B to B′, the Wheel will remain stationary. The Hinge V starts from v′, pushing through v to V_0, after which it

pulls through V to V', so that the instrument starts in a closed form with $\beta = -2\pi$, opens completely, and then closes again with $\beta = 2\pi$.

If now the whole closed instrument be revolved about C from the position C V' B' to C v' b', the Wheel will measure minus B' b', the value of which is $b - c$ multiplied by the angle B' C b, which has already been proved equal to $2(p-1)\pi$, so that the Reading is

$$R = -\text{B' b'} = -2\pi(p-1)(b-c),$$

and the circuit of the leaf is complete if the inner end of it is really B' b'. But β has not been returned to its initial value -2π, and therefore the area has not been correctly measured. To do this revolve the Measuring-Bar clockwise once around the Hinge at v'. This will return the Wheel to b' again and β to its first value -2π, adding to the area the circular area πb^2, and to the Reading $2\pi b$.

Multiplying the Reading by b and adding the o-Circle area, gives for the total area, $2\pi[b^2 - (p-1)(b^2 - bc)] + \pi(c^2 - b^2)$.

If from this be subtracted again the circular area πb^2, which was added, there results for the

Area of the leaf to B'b',

$$A = \pi b^2 - 2(p-1)\pi(b^2 - bc) + \pi(c^2 - b^2)$$

The imaginary radius of the o-Circle is $\sqrt{c^2 - b^2}$. Completing now the sector C Z' z' to the radius $i\sqrt{c^2 - b^2}$ and supposing it to lie in a production of the plane of the leaf, formed by producing all the radii, as B' C backwards through the center C, the arc Z' z' represents the arc of the o-Circle which forms the inner end of the leaf, so that, as in the first form, the area is bounded by portions of the Tractrix and o-Circle and by the radii B' Z' and b' z' connecting their ends.

The area of this double sectoral area is

$$\text{Area of Sector} = (p-1)\pi[(b-c)^2 + i\sqrt{(c^2 - b^2)^2}]$$
$$= 2(p-1)\pi(b^2 - bc),$$

the produced part coming minus in accordance with the previous discussion under "CROSSED BOUNDARIES."

Adding this to the above gives the

Area of the complete leaf

$$A = \pi c^2,$$

as given by the formula.

LENGTH s OF THE TRACTRIX.

Let the Measuring-Bar be moved from B V to its consecutive position $B_1 V_1$ by moving it endwise to B_1 v and then revolving it around B_1 until the hinge reaches V_1 distant c from C, as shown in Fig. 53.

The differential equation can then be written,

$$ds = c d\gamma \cdot \Lambda\beta,$$

which reduces to

$$ds = c\Lambda\beta \frac{-\gamma\beta_0}{\gamma\beta - \gamma\beta_0} d\beta$$

by means of the Differential Equation of the Polar Tractrix.

Inasmuch as $-\Lambda\beta$ is the differential of the denominator, the expression integrates at once to

$$s = c\gamma\beta_0 \cdot lg \frac{\gamma\beta - \gamma\beta_0}{1 - \gamma\beta_0}$$

the constant denominator being introduced to make

$$s = 0 \text{ when } \beta = 0.$$

By introducing $b = -c\gamma\beta_0$ this becomes

$$\frac{s}{b} = lg \frac{1 - \gamma\beta_0}{\gamma\beta - \gamma\beta_0} = lg \frac{c + b}{c\gamma\beta + b}.$$

This last expression is the most general and gives the length of the curve for both forms of the Tractrix, with the exception that for the inner branches of the first form it, as well as the expression containing β_0, becomes imaginary, while for the second form it is also limited to a single branch because $\gamma\beta$ has the same value for minus angles as for plus.

The first defect requires such a change in the constant of integration as shall make

$$s = 0 \text{ when } \beta = \tfrac{1}{2}\pi,$$

so that the length of the curve for an inner branch must be reckoned from the cusp B_0'. Both cases may however be included in the one expression for the

Length of Polar Tractrix,

$$\frac{s}{b} = \frac{\pm 1 - \angle \beta_0}{\angle \beta - \angle \beta_0} = lg \frac{\pm c + b}{c \angle \beta + b}$$

where the upper sign refers to an outer branch reckoned from B_0 and the lower to an inner branch reckoned from B_0'.

The second defect could be remedied, theoretically, by the introduction of γ, but this would complicate the expression too much, there being no necessity for getting the length of more than one branch.

The length to the point of inflection, where $\angle \beta = 0$, is

$$s_1 = b\, lg\, (b + c) - lg\, b,$$

which is true for both forms and equals $b\, lg\, 2$ when $c = b$.

The length of a branch of the second form, or half leaf, is found, by putting $\beta = \pi$, to be

$$s' = b\, lg \frac{b + c}{b - c} = 2b\, lg \sqcup \tfrac{1}{2}\beta_0'.$$

When $c = 0$ the length of the branch is zero.

A consideration of the formula shows that the reason that it cannot be used for more than a half leaf is that s acquires the plus sign for pulling branches only, becoming minus for pushing branches, so that for $\beta = 2\pi$ the sum of a pulling and pushing branch is given as zero.

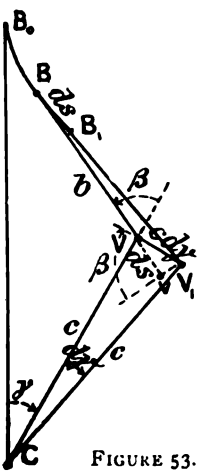


FIGURE 53.

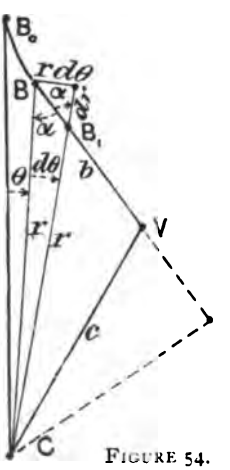


FIGURE 54.

EVOLUTE OF THE POLAR TRACTRIX.

The Exponential Equation of the Polar Tractrix may be made explicit for β, so that

$$\frac{\lrcorner \frac{1}{2}\beta}{\lrcorner \frac{1}{2}\beta_0} = \frac{e^z \mp e^{-z}}{e^z \pm e^{-z}} = (\textit{hyperbolic tangent } z)^{\pm 1}$$

where $z = \lrcorner \beta_0 \cdot \frac{1}{2}\gamma$, and $\pm$ refers to the outer and inner branches respectively.

In Fig. 43 J is the instantaneous center for the Measuring-Bar B V, which is always tangent to the Tractrix at B the evolute is therefore the locus of J.

Putting J C $= j$, the values of twice the sine and cosine squared of half β from the figure are

$$2\Lambda^2 \tfrac{1}{2}\beta = 1 - \nearrow\beta = \frac{j-c-b}{j-c}$$

$$2\nearrow^2 \tfrac{1}{2}\beta = 1 + \nearrow\beta = \frac{j-c+b}{j-c},$$

which, with the help of the above Equation of the Tractrix leads to the *equation of the Evolute of the Polar Tractrix*,

$$\frac{j-c-b}{j-c+b} = \lrcorner^2 \tfrac{1}{2}\beta_0 \frac{(e^z \pm e^{-z})^2}{(e^z \pm e^{-z})^2} = (\lrcorner \tfrac{1}{2}\beta_0 \cdot \textit{hyp. tang } z)^{\pm 2}.$$

For the *common tractrix* $\beta_0 = \frac{1}{2}\pi$, and the equation reduces to the simpler one

$$j = c \pm b \cdot \tfrac{1}{2}(e^{2z} + e^{-2z})$$

equals c plus or minus b times the *hyperbolic cosine* of $\lrcorner \beta_0 \cdot \gamma$, so that in the common tractrix the secant of β equals plus or minus this hyperbolic cosine.

POLAR EQUATION OF THE POLAR TRACTRIX.

It is instructive to produce the equation between r and θ, as it shows in a marked degree how much the simplicity of a problem may depend upon the choice of suitable co-ordinates.

In Fig. 54 dr is minus while $d\theta$ is plus, therefore in the triangle B b B_1 with $\nearrow$ and $\lrcorner$ for cosine and tangent,

$$\frac{r d\theta}{-dr} = \lrcorner \alpha ;$$

also in the triangle C B V

$$\angle \alpha = \frac{r^2 + b^2 - c^2}{2rb}$$

from which

$$\angle \alpha = \frac{\sqrt{-r^4 + 2(c^2 + b^2) r^2 - (c^2 - b^2)^2}}{r^2 + b^2 - c^2}.$$

Equating these values the equation reduces easily to the

Differential Equation between r and θ,

$$2i\, d\theta = \frac{r^4 - 2(c^2 + b^2) r^2 + (c^2 - b^2)^2}{r^2 (r^2 + b^2 - c^2) \sqrt{r^4 + 2(c^2 + b^2) r^2 - (c^2 - b^2)^2}}\, d(r^2).$$

Putting $z = r^2$

$$m = c^2 + b^2$$
$$n = c^2 - b^2$$
$$Z = z^2 + 2mz - n^2$$
$$N = Z \text{ when } z = n$$
$$M = b^2 \div (b^2 - c^2)$$

and separating the fraction into three others, the equation becomes.

$$2i\, d\theta = \frac{dz}{\sqrt{Z}} - n \frac{dz}{z\sqrt{Z}} - 2(n - m) \frac{dz}{(z-n)\sqrt{Z}}$$

Integrating this gives

$$\begin{aligned} 2i\theta = {} & lg\,(z - m + \sqrt{Z}) \\ & + lg\,(z + n + \sqrt{Z}) - lg\,(z - n + \sqrt{Z}) \\ & + 2\sqrt{M}\, lg\,(z - n + \sqrt{Z} - \sqrt{N}) \\ & - 2\sqrt{M}\, lg\,(z - n + \sqrt{Z} + \sqrt{N}) + const. \end{aligned}$$

An equation of much greater complexity than is required with the more suitable co-ordinates already used.

SPHERICAL AREAS.

Amsler's Planimeter for plane areas is a special case of a more general form which will measure areas upon the surface of a sphere.

Figure 55 shows such an instrument. It differs from the ordinary planimeter principally in having two stiff hinge joints I and J at the centers of the Measuring and Radius Bars respectively. The axes of these joints being perpendicular to that of the Hinge V, they allow the bars to be bent, as shown in the figure, so that the

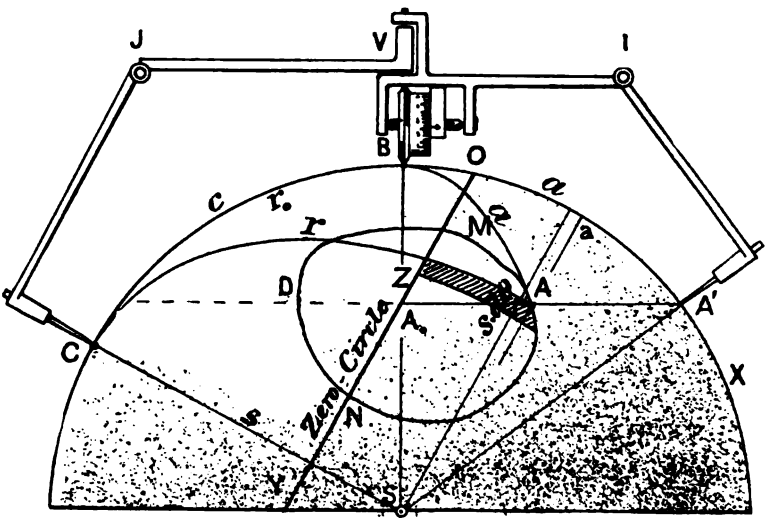


FIGURE 55.

Stylus A′, Hinge V, and Needle-Point C all point to the center S of the sphere. By mounting the Wheel so that its center B is directly beneath the Hinge no adjustment is needed to make it support the Hinge at the same distance from the center S on spheres of different radii, and the Wheel-Plane passes always through that center.

The instrument is drawn in the *open* position the better to show its construction. A partial revolution of the Measuring-Bar about the Hinge, while the Radius-Bar remains fixed, brings the Stylus from A′ to A, where it is supposed to be at work measuring the area A N D M.

When the Stylus is brought to A_0 the Wheel-Plane passes through C and β assumes the value $\beta_0 = \frac{1}{2}\pi$. If then the instrument be revolved as a whole about C, β retaining the value β_0, the Stylus describes the Zero-Circle O Y, a small circle of the sphere about C as a pole. O Y being the axis of ordinates the axis of abscissas is the great circle O X. All quantities, as a, c, s, etc., are supposed measured in the same *linear* unit.

If in the same way a small circle Aa parallel to the o-Circle be described through A with a fixed value of β, it and the o-Circle define a zone of the sphere of which A Z is the elementary area.

To simplify the typography of the following analysis the division of a quantity by s will be indicated by using Roman instead of italic letters, thus; a means $a \div s$. $\wedge$ and $\nearrow$ will be used for *sine* and *cosine* as before.

The differential element of the zone has the area

$$Area\ \mathrm{A\,Z} = dA = s\,(\nearrow \mathrm{r}_0 - \nearrow \mathrm{r})\,.\,s\,d\theta.$$

To find its value in terms of the Reading R the spherical triangle A B C, with sides c, r, and a, equal to the curved length of the Radius-Bar, the variable radius of the Stylus and the curved length of the Measuring-Bar respectively, must be used to obtain

$$\nearrow \mathrm{r} = \nearrow \mathrm{a} \nearrow \mathrm{c} - \wedge \mathrm{a} \wedge \mathrm{c} \nearrow \beta,$$

which becomes for the Stylus at A_0

$$\nearrow \mathrm{r}_0 = \nearrow \mathrm{a} \nearrow \mathrm{c},$$

so that

$$\nearrow \mathrm{r}_0 - \nearrow \mathrm{r} = \wedge \mathrm{a} \wedge \mathrm{c} \nearrow \beta$$

and

$$dA = s^2 \wedge \mathrm{a} \wedge \mathrm{c} \nearrow \beta\ d\theta.$$

The same reasoning as was used with Fig. 6 shows that the Wheel registers only as A passes over the outer end of the elementary area, and the differential distance thus measured off by the circumference of the Wheel is

$$dR = s \wedge \mathrm{c} \cdot \nearrow \beta \cdot d\theta$$

so that

$$dA = s \wedge \mathrm{a} \cdot dR$$

or, by integration,

$$A = s \wedge \mathrm{a}\,(R + nR_0)$$

Inasmuch as $s \wedge \mathrm{a}$ is the perpendicular distance of the Stylus point from the Hinge axis, it is the effective length of the Measuring-Bar and equivalent to a in the ordinary planimeter. R_0 is also the Reading for the area C O Y of the o-Circle, so that the formula is the same as, and for an infinite sphere reduces to, that obtained for the common instrument.

If C is not included in the area measured, R_0 disappears, as n then is zero; on the other hand C may be included in the area n times, as explained for the ordinary planimeter. The Wheel is, of course, supposed to be graduated to read inches measured off by its circumference, or whatever linear unit is to be employed in the measurements. $s \wedge a$, the effective length of the Measuring-Bar, will evidently be different for different spheres, its value could be tabulated and the setting of the joint I for any particular sphere could thus be verified.

When c is equal to a quadrant of the sphere the o-Circle is a great circle and the instrument corresponds in its proportions with an ordinary planimeter in which $c = \infty$.

MOMENT PLANIMETERS.

It has thus far appeared that a *rolling wheel* may be used to measure the length l of a straight or curved line, over which it is rolled, the wheel plane remaining tangent to the line. It therefore integrates mechanically the expression

$$l = \int dl$$

Also, if A is the area within any boundary and dA an element thereof, a *rolling and sliding wheel* furnished with mechanism to suitably proportion the rolling to the sliding, will act as a *mechanical integrator* for the expression

$$A = \int dA$$

but in rectangular co-ordinates

$$dA = xdy$$

therefore such a wheel will integrate the expression

$$A = \int xdy$$

But the resources of *rolling and sliding wheels* are by no means thus exhausted and instruments are made to integrate

$$M = \tfrac{1}{2}\int x^2 dy$$

$$I = \tfrac{1}{3}\int x^3 dy, \text{ etc.,}$$

and called *Moment Planimeters*, $\frac{1}{2}x$ being thus regarded as the lever arm of xdy, so that M becomes the statical moment of the area A.

Figure 56 shows the general scheme of such an instrument, which consists of a Measuring-Bar A V hinged to a frame C, not shown, furnished with rollers following a straight track D E so that the length of the Measuring-Bar is $a = A V$, and that of the Radius-Bar is $c = V$ to infinity, as in *Coffin's Averaging Instrument*, already described. Its Wheel W_1 gives therefore a Reading for areas, like the ordinary planimeter.

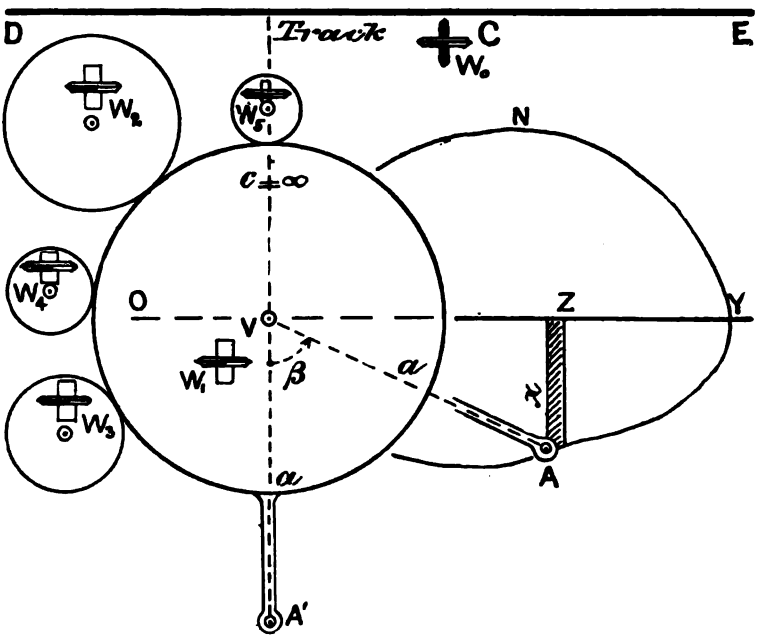


FIGURE 56.

The Measuring-Bar has, however, a wheel of any large radius attached to it concentric with the Hinge V, and upon the frame are mounted any number, $n - 1$, smaller wheels, whose radii are respectively one-half, one-third, one-quarter, etc., the large radius, and whose circumferences are held tightly in contact with the large circumference so as to give these wheels respectively twice, thrice, four times, etc., the angular motion of the large wheel.

Anywhere upon each of the n wheels is mounted a Measuring-Wheel in such a manner as to be always in contact with the paper, or other surface beneath it, and to roll and slide thereon. Another Measuring-Wheel W_0 may, to complete the series, be mounted upon the frame itself. When $\beta = 0$ the instrument takes the "open" position with the Stylus at A', as shown in the figure, and the Measuring-Wheels must have their axes carefully set at right-angles with D E.

If now the whole instrument be rolled any distance along D E, the Hinge V will follow the axis O Y, and all the Wheels will roll that distance over the paper without sliding. To simplify the conception, suppose that a, the length of the Measuring-Bar, be taken for the unit of measure, so that lengths will be expressed as so many times a, areas as so many times a^2, etc., and let the Measuring-Wheels be so graduated that for each distance a *rolled* by a Wheel its Reading increases by unity. Then, if all the Wheels read "zero" to start with, they will all read "one" when the instrument has moved along D E the distance a.

If now β be increased from 0, its value when the instrument is fully open, to β, the angle which V A makes with V A', thereby bringing the Stylus into the position A, the sliding-frame on which the Measuring-Wheel W_0 is mounted is not affected by the change, but wheel 1, which carries the Measuring-Arm, revolves through 1β, wheel 2, which carries the Measuring-Wheel W_2, revolves through 2β, wheel 3 through 3β, etc.

If in this position of the wheels the whole instrument be rolled along the track a distance dy, carrying with it, of course, the wheels mounted on it, with the Wheels mounted on them, the Hinge V will follow O Y and the Wheels will record the respective distances dy, $\int \beta.dy$, $\int 2\beta.dy$, $\int 3\beta.dy$, etc., and from their Readings the values of the integrals already referred to can be obtained.

So far as dy and $\int \beta dy$ are concerned, they have already been seen to be in the proper form, and, with a for the unit of measure,

the ordinate x, or length of the *elementary area* A Z, is the cosine of β, and $\nearrow \beta dy$ is the differential area.

To show the relation between the Readings of the Wheels and higher integrals it is necessary to develop the cosine of n times β, or $\nearrow n\beta$, or, more simply, $\nearrow n$, in terms of $\nearrow \beta$, or, more simply, $\nearrow$, omitting β from the formula for brevity.

Thus,

$$\nearrow n = \text{A} \nearrow^{n} + \text{B} \nearrow^{n-2} \ldots + \text{K} \nearrow^{n-2m} + \text{L} \nearrow^{n-2m-2} \ldots + \text{Q} \nearrow^{1}$$

$$\text{or} \ldots . \text{P} \nearrow^{2} + \text{Q} \nearrow^{0}$$

with $(n - 2m)(n - 2m - 1)\,\text{K} = -4(n - m - 1)(m + 1)\,\text{L}$

and $\text{A} + \text{B} + \text{C} \ldots\ldots + \text{P} + \text{Q} = 1$

to determine the values of the coefficients. It comes out that

$\text{A} = 2^{n-1}$, also;

For n an even multiple of 2, $\text{Q} = 1$;

For n an odd multiple of 2, $\text{Q} = -1$;

For $n - 1$ an even multiple of 2, $\text{Q} = n$; and

For $n - 1$ an odd multiple of 2, $\text{Q} = -n$;

so that a series may be written out by means of the equation between K and L, starting from either end and checking its correctness at the other.

The general value of the coefficient of the cosine $(n - 2m)\,\beta$ is

$$\text{K} = (-1)^{m} \cdot 2^{n-2m-1} \frac{1 \cdot (n - m - 1)(n - m - 2) \ldots . (n - 2m + 1)}{1 \cdot 1 \cdot 2 \cdot 3 \ldots . m}$$

The inverse series may be written thus;

$$\tfrac{1}{2}(2 \nearrow)^{n} = \nearrow n + B \nearrow (n-2) \ldots . + K \nearrow (n - 2m) \ldots .$$

$$+ Q \nearrow \text{ or } P \nearrow_{2} + Q \tfrac{1}{2} \nearrow_{0},$$

the values of the coefficients of the (cosine $\beta)^{n-2m}$, being

$$B = n;\ C = \tfrac{1}{2} n (n - 1);$$

$$K = \frac{1 \cdot n \cdot n - 1 \cdot n - 2 \ldots . n - (m + 1)}{1 \cdot 1 \cdot 2 \cdot 3 \ldots . m}$$

The relations between the cosines of the multiple angles and the Readings are

$$dR_{0} = dy \qquad dR_{1} = \nearrow \beta \cdot dy$$

$$dR_{2} = \nearrow 2\beta\, dy \qquad dR_{n} = \nearrow n\beta \cdot dy.$$

Substituting which in the series, after multiplying it through by dy, and integrating, there results

$$2^{n-1}\int 7^n \beta\cdot dy = R_n + n R_{n-2} + \tfrac{1}{2}n\,(n-1)\,R_{n-4}\ldots. + K R_{n-2m}\ldots. + Q R_1$$

for n odd, or, for n even $\ldots. + P R_2 + \tfrac{1}{2} Q R_0$.

For a closed curve the integral $R_0 = \int dy$ is always zero, so that the term $\frac{1}{2}QR_0$ disappears from the formula. For example, for a closed curve,

$$\int 7\beta\cdot dy = R_1 \qquad 2\int 7^2\beta\cdot dy = R_2$$

$$4\int 7^3\beta\cdot dy = R_3 + 3R_1 \qquad 8\int 7^4\beta\cdot dy = R_4 + 4R_2$$

$$6\int 7^5 dy = R_5 + 5R_3 + 10R_1 \qquad 32\int 7^6 dy = R_6 + 6R_4 + 15R_2,$$

from which the area, moment, moment of inertia, etc., are easily deduced.

The intention in this article being to outline the general scope only of a moment planimeter and not to discuss its peculiarities, it is sufficient to conclude here with the statement that while OY is still the o-Circle for R_1, other wheels have each their own o-Circles, n in number, symmetrically disposed about OY.

If any other unit than a is desired, a multiplication of the results by r^{n+1} is necessary, n being the power to which the cosine under the integral sign is raised, or the subscript of the highest Wheel read, and $r = a$ divided by the new unit.

It is possible to make a moment planimeter that will work upon the surface of a sphere and give the moment of an area with respect to an equatorial plane.

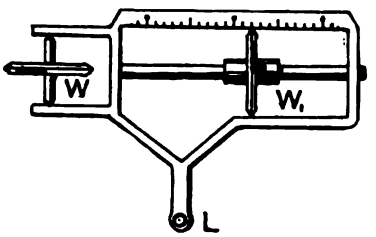
SLIDING-WHEEL PLANIMETER.

Figure 57 represents a frame similar to that already shown in Fig. 4, with two Wheels and a leg L to steady it as it is moved over the paper. It is not, as already stated, a planimeter, but simply a mechanism to illustrate the action of Measuring-Wheels. In this figure the Wheel W_1 is not, like that in Fig. 4, a duplicate of W, but is mounted upon a fixed axis so that it is free both to roll and slide

thereon. Its axis lies in the plane of the Wheel W and its position upon its axis is indicated by the graduated scale upon the frame.

Bearing in mind the previous explanation in connection with Fig. 4, and even without, it must be evident that for any possible motion of the frame over the paper the sliding of the Wheel W_1 along its axis, is equal to the rolling of W upon the paper, any component of the motion at right angles to the W_1 axis being provided for by the sliding of W on the paper and the rolling of W_1.

FIGURE 57.



The Measuring-Wheel in Amsler's Planimeter may therefore be mounted at right angles to its usual position, like W_1, and the Readings made on a scale as shown, and instruments are thus made. It is difficult, however, to see much advantage in the change, inasmuch as the linear scale is limited in length, and the sliding friction along the axis is often much greater than the friction of the nicely pivoted Wheel W. The linear scale, however, admits of being changed to suit various kinds of work.*

* A planimeter with interchangeable scales is made by E. J. Willis, M. E., of Richmond, Va.

The accompanying Fig. 1 represents a well rig ready for drilling wells with a maximum diameter of 12 inches and a total depth of 3,000 feet; the cut was kindly loaned by the Oil Well Supply Company. It consists essentially of a substantial derrick for supporting the drilling, cleaning, and fishing tools, which, with the boiler, engine, pulleys, and walking-beam, are supported on suitable foundation timbers.

To commence operations the derrick T is placed over the proposed well. At the top of the derrick is secured the crown pulley *i*, over which the cable or drill rope plays. The bull-wheels R with shaft are attached at the lower right-hand end of derrick. The drilling cable is fastened and coiled on the bull-wheel shaft, the outer end of cable passing under the shaft and led up over the crown pulley *i*. The office of the bull-wheels is to raise and lower the tools in the well. The samson post is shown at I, supporting the walking-beam J, from which are suspended the drilling tools while drilling the well. The walking-beam is connected to the band-wheel L by the pitman M. The band-wheel is driven by belt connection from engine. On the side of the band-wheel L is bolted the tug pulley, which, by means of a rope (not shown on cut), drives the bull-wheels. The tools are lowered in the well by their own weight, and to check the rapidity of descent one of the bull-wheels is provided with a brake *g*. At K is shown the sand reel, on the shaft of which are secured both a brake and friction pulley. The shaft of reel is placed so that a line drawn from the center of the sand-pump pulley at the top of derrick will cut the shaft at right angles, which position allows the sand-pump rope to distribute itself evenly from end to end of the shaft. The engine is separated a suitable distance from the band-wheel to obtain proper contact for the belt. The engine throttle is under control of the driller in the derrick by the endless cord *t*, called the telegraph. The position of the engine link can be changed by the cord *u*, thus running the engine in either

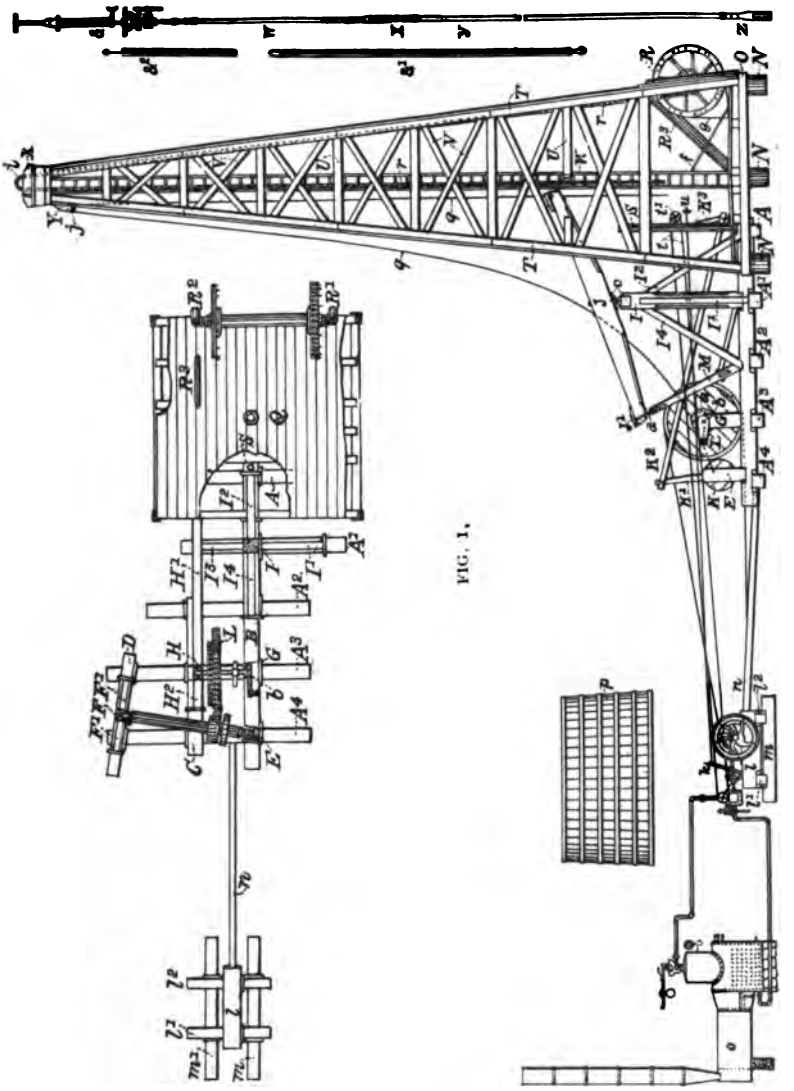


FIG. 1.

direction. When the cord *u* is slackened the link drops by its own weight.

The headache post S is placed directly under the walking-beam, and in case of accident to the pitman M or saddle C the

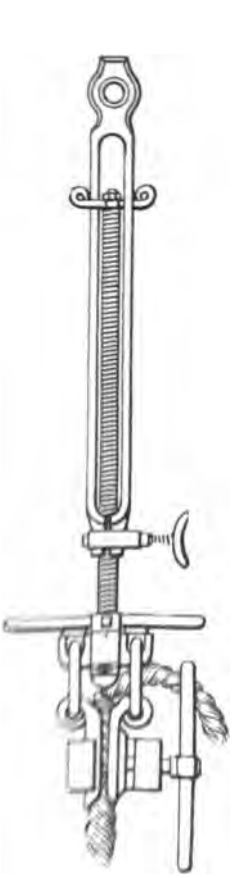


FIG. 3. Sinker Bar.

FIG. 4. Jars.

FIG. 5. Auger Stem.

front end of the walking-beam will drop upon it, and thus be prevented from causing any injury. This headache post is also used

as a support for the walking-beam when repairs are made to the crank or pitman.

Attached to the derrick floor near the grooved bull-wheel R^2 is a block swinging on a pivot having a projecting pin at one end, and at the other a cord long enough to reach the operator at the brake. The lever is so arranged that a pull of the cord will swing the pin against the bull rope and throw it off the pulley.

The drilling tools are shown on the right of the derrick in Fig. 1, and also in Figs. 2, 3, 4, 5, 6, 6A, and 7.

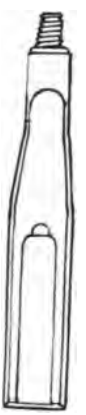


FIG. 6
Drilling Bit.

FIG. 6A.
Drill Gauge.

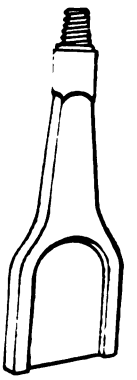


FIG. 7.
Spudding Bit.

FIG. 8.
Horn Socket.

The other essential tools are the fishing tools, a few of which are shown in Figs. 8, 9, 10, and 11, a pair of heavy wrenches, as per Fig. 12, a bailer, Fig. 13, and sand pump, Fig. 14.

The novelty of the jars requires special mention. They are made in two parts, the crosshead of one passing through the slot of the other. When extended they are about 9 inches longer than when closed. The office of the jars is to give a blow upward to loosen the tools in case they should stick fast.

The elasticity of the cable is taken advantage of by drilling on "the spring of the cable." This desirable result is obtained by suspending the tools so that they reach within 5 inches to 2 feet from the bottom of the well hole, when the end of walking-beam

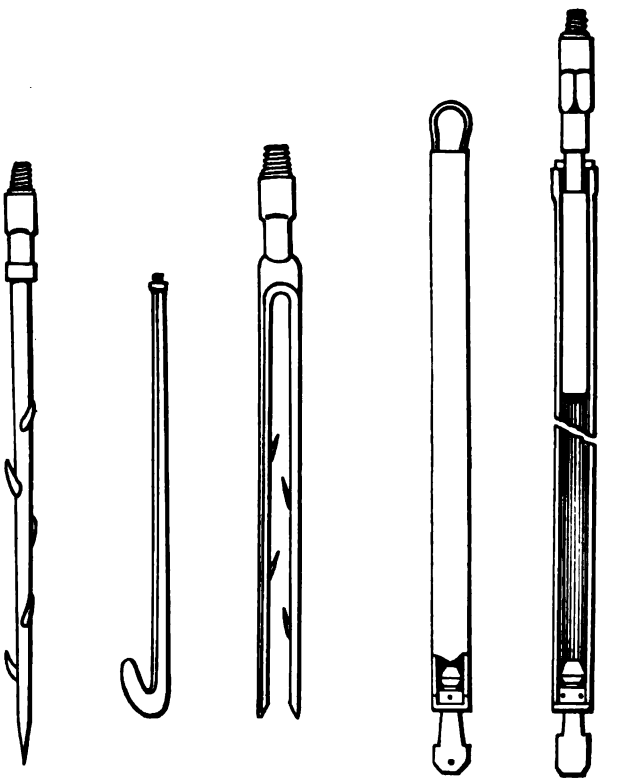


FIG. 9. Rope Spear. FIG. 10. Hook Rope Knife. FIG. 11. Rope Grab. FIG. 13. Bailer. FIG. 14. Sand Pump

supporting the tools is at its lowest position, this distance depending on the length and consequent spring of the cable. When motion is given to the walking-beam the tools rise and fall in the hole. Their weight stretches the cable until they touch the bottom and

bound from it, giving a quick rebounding blow called "bouncing the drill."

The temper screw makes the connection between the hook on walking-beam and the cable, which is gradually let out as the bit cuts into the rock. The clamps at the lower end of screw are fastened to the cable. The temper screw when let out its full length reaches from the walking-beam, while at its lowest position, to very near the mouth of the well.

The lower end of temper-screw yoke is encircled by a band, which is riveted to one of the prongs of yoke, and a set screw through the band keeps the other prong in place. The lower end of yoke terminates in a divided nut which can spring apart when released. If the driller wishes to pay out the temper screw, he

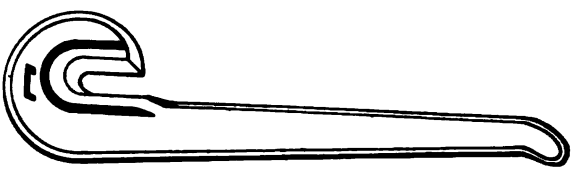


FIG. 12.—Wrench.

turns it by loosening the set screw in the band. When the screw is all run out and the clamps disconnected from the cable, the yoke is allowed to open and the temper screw raised.

Bailers and sand pumps are used to empty and clean the well. The bailer as shown in Fig. 13 is an ordinary hollow cylinder with foot valve on bottom. The sand pump, Fig. 14, is nothing more than a suction pump with foot valve and plunger.

In commencing a well, if the earth is firm, a hole is first "spudded" with a spudding bit and cased to the rock. If the soil is of a sandy nature, the casing capped with a steel shoe, is driven to the rock, operating the spudding bit and sand pump as the pipe sinks. The casing is driven pile-driver fashion, motion being

given to a heavy maul suspended in the derrick, by fastening a rope to the wrist pin of the band-wheel L, Fig. 1, and tying same loosely around the cable from which the maul is suspended. The engine is started and every revolution of the crank raises and drops the maul. The cable is let out as the pipe sinks. Sometimes the pipe is driven by bolting drive clamps to auger stem and operating the tools as if spudding. The effect of the blows imparted by the clamps, to the collar screwed on the pipe, sinks it in place.

The drilling tools, on account of their length, cannot be operated in the regular way until the hole is deep enough to allow them to sink beneath the derrick floor. The first 50 or 60 feet are "spudded" as stated above, the operation being to take the end of the short cable used in driving pipe and disconnecting same from the maul, and attaching it to the sinker bar or auger stem and a bit, then raising and lowering the tools in a manner similar to the method just described to drive pipe. Water is poured into the hole, and the sand pump operated to clean out the well. On reaching bedrock the hole is drilled into it a few inches and the drive pipe firmly driven in, to form a tight union, which prevents surface water or foreign matter from entering the well. When the hole has reached the necessary depth to bury the tools, the cable is coiled upon the bull-wheel shaft, and its end united to the tools, which are suspended in the derrick. The temper screw is closed and attached to the drilling hook, the clamps of the screw being tightened on cable. The pitman is connected to the wrist pin of the crank. The cable is then slackened off from the bull-wheel, and the tools hang in the well suspended from the walking-beam. The engine is started and the tools rise and fall with each rotation of the crank. The attendant turns the clamps (which are united to the temper screw by a swivel) until the slack of the rope is coiled a number of times around the straight cable below the temper screw. The motion is then reversed, which uncoils the rope and recoils it the other way. By this means

the drill is constantly turned while drilling. The operator feeds out the temper screw as the drill penetrates the rock. A new hold is taken on the cable by means of the clamps, when the screw has been fed out its entire length.

The tools are withdrawn when the bit requires dressing, the operation being to throw the tug rope on the bull-wheel, which on turning takes up the slack of the cable. The

Wrench Circle Bar.

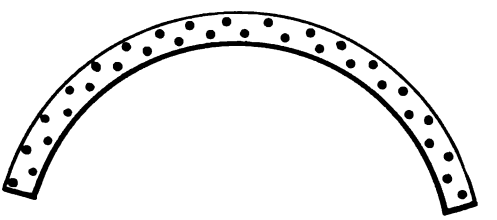


FIG. 15.—Wrench Circle.

engine is stopped as the cable is tightened, to release the clamps of the temper screw from the cable. The pitman is disconnected from the crank and lowered to the main sill. The engine is then run until the squared portion of the bit appears to apply a wrench. Another wrench is put on the squared part of the auger stem just above the box. A bar is inserted in

one of an arc of holes in the wrench circle, Fig. 15, which, being firmly fastened to the derrick floor, allows a purchase for the bar when forced against one of the wrenches, the other wrench being held by a link to wrench circle. This enables the operator to start the joint, so that it can be unscrewed by hand. Then the engine is again started to raise the tools entirely out of the hole. When the bit is drawn out the engine is stopped, the bull-wheel brake put on, and the tools swung out of the way to allow a bailer or sand pump to be operated in the well. The bit is unscrewed and another put in place ready for operation, the worn-out bit being in the meantime dressed. The sand pump or bailer runs down the well by its own weight and is withdrawn by pulling on the lever K^3, Fig. 1, which holds the friction pulley K against the face of the band-wheel L. The speed of the sand pump in either direction is regulated by pushing the lever K^3 and throwing the brake pulley which is on same shaft with K against its back brake.

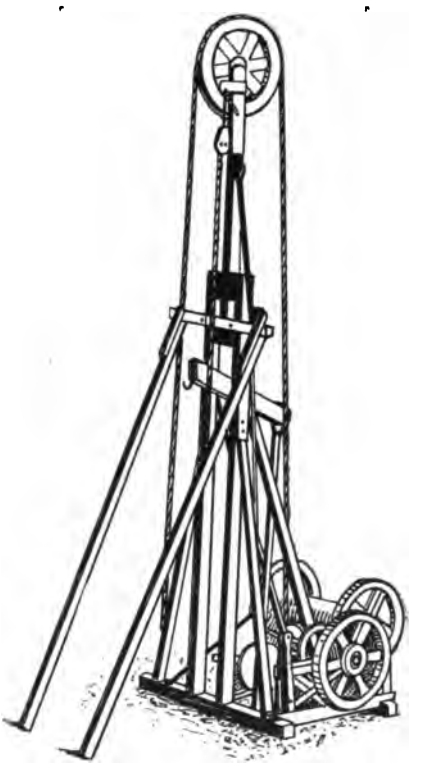
The well is cleaned, and the tools lowered a short distance to tighten the joint between the bit and auger stem, after which the tools are lowered to the bottom of the well, their rapidity of descent being controlled by the brake *f*. Connections are made and the drilling resumed.

The diameter of the well in the rock is sometimes smaller than the inside diameter of the casing or drive pipe, especially if there is any danger of the well hole not being drilled plumb.

The piping to lead the water from the water-bearing stratum to the surface is next placed in the well, which in case of a non-flowing well has a working barrel or other mechanism attached to force the water to the surface. In case any water veins have been struck above the strata which are to be used, the upper veins are closed off with packers made of rubber or flaxseed.

The rubber "packer" is generally made of a hollow cylinder of rubber surrounding the well tubing, and secured between flanges ·ected by a slip joint, the lower pipe or tubing resting on the bot-

tom of well, and the weight of the tubing above the slip joint, pressing upon the rubber, distends it against the side of the well and tubing, forming a tight joint. Sometimes a bag of leather containing flaxseed is fastened to the tubing, which on being lowered into the water expands the flaxseed and makes a tight union.



When a well does not give a sufficient quantity of water, the flow is sometimes increased by exploding a torpedo at the depth of the water-bearing stratum, which opens fissures in the surrounding rock. Torpedoes are made by filling suitable shells with charges

of nitro-glycerine varying in quantity from a few quarts to a hundred quarts. On exploding, the water above the shell is shot into the air followed by a discharge of gravel and small stones. The torpedo shell is blown into such small fragments that they form no obstruction to after operations.

In drilling a deep hole the cable may be broken and the tools dropped to the bottom of the well. When this occurs the skill and ingenuity of the driller are tested. Figures 8, 9, 10, and 11 show some of the fishing tools used in case of such accidents.

Many other designs of drilling rigs are manufactured, but most of the machines are modifications of the walking-beam rig shown in Fig. 1. Some of the smaller machines are mounted on trucks, making them very desirable for prospecting, when shallow wells of small diameters are to be drilled.

Another method of drilling wells is by means of an apparatus which may be termed a hydraulic drill. It consists essentially of a hollow drill suspended by piping, which is raised and dropped as the ordinary solid drill. Water is pumped down the piping and through the drill while drilling. The drill pierces its way downward, and the water with the debris finds its way upward between the outside of the piping and sides of the well. In sandy soil this method of drilling is becoming very popular on account of its efficiency.

A driven well is sunk by forcing casing or drive pipe pile-driver fashion through the soil until a water-bearing stratum is reached. The first length of pipe driven is provided with suitable perforations, covered with wire gauze, and capped by a stout well point. Sometimes the method of procedure is to drive a pipe of large diameter, say 8-inch pipe, using the hydraulic drill to clear the way. When a water-bearing stratum is reached, the well pipe proper is lowered into it, being in this case 6-inch pipe, in the first length of which are drilled perforations covered with fine wire cloth. Then the 8-inch pipe is raised and a 6-inch well is secured

without any liability of having injured the wire cloth while being put in place.

Driven wells can only be efficiently driven in gravel and sandy soils. If the sand is too fine it may cause much annoyance by closing up the strainer holes, or find its way up the well tubing and injure the pumping machinery.

The sand is sometimes gotten rid of by driving a well pipe with open end, and after being in place, pumping up a portion of the fine sand near its extremity. This process collects the coarser gravel around the end of pipe, forming a gravel filter. When no gravel can be collected in this way, it is sometimes the practice to drop gravel down the well pipe, and with the aid of the drilling tools force it out of the pipe, forming an artificial gravel filter bed. At other times a pipe open at the end is driven into the sand to the water-bearing stratum, and pumped to take away some of the sand. Gravel is then forced down the pipe into the cavity. The drive pipe is then raised, and another pipe with perforation, covered with wire cloth and capped by a well point, is driven into the gravel bed.

Through earth where there is no rock, wells have been bored with augers. The boring tool is suspended by a cable from a derrick, and a rotary motion is given to the auger, which penetrates its way into the earth. If the earth is dry water is poured into the well hole so that the material will more easily travel up the boring tool. The auger filled with earth is raised by the winch on the tripod or derrick. This method is only applicable for shallow wells and is not in general use.

In this connection may be mentioned wells bored with the diamond drill, which consists essentially of a hollow spindle, with a drill head attached to its lower end. In this head are fastened cutting diamonds, so secured that when the spindle is rotated it cuts its way through the rock, leaving a core in the center. Water is pumped down the spindle, which, rising outside, carries away

Owner.	Location.	Diam. in Inches.	Total Depth in Feet.	Depth of Casing to Rock in Feet.	Capacity per Minute in Gallons when Pumped.	Flow per Minute in Gallons.	Nature of Strata Drilled Through.	Remarks.
De Ford & Co.....	Covington, Va.	8	700	22	Moderate.	..	Slate.	Fissures in rock vertical.
Hartford Light & Power Co.	Hartford, Conn.	10	615	35	250	10	Red shale.	
Reid & Barry.....	Passaic, N. J.	12	300	78	500	5	Red shale.	
Plainfield, N. J.	Plainfield, N. J.	Four 10	50	...	750 each well.	....	Clay, sand, and gravel.	
South Plainfield, N. J.....	South Plainfield, N. J.	Three 12	200	12	600 each well.	100 each well	Red shale.	
Colgate & Co....	Jersey City, N. J.	8	1500	35 ft. 8" casing; 300 ft. 5⅝" "; 1200 ft. 5⅝" hole in rock.	Moderate.	...		
Manhattan Life Ins. Co....	New York City.	8	1056	35	75	....		
City of Brooklyn, N. Y.....	Brooklyn, N. Y.	Ten 6	60	....	3500 total.	....	Sand and gravel.	
Baltimore Sugar Ref. Co...	Baltimore, Md.	Seven 8	160	....	1750 total.	....	Clay and sand.	
Graham Land & Imp. Co...	Graham, Va	8	300	50	100	....	....	Iron and sulphur in water.
Elizabeth Ice Co.....	Elizabeth, N. J.	6	300	20	200	. ..	Red shale.	
H. De B. Parsons.....	Rye, N. Y.	6	85	4	1	....	Gneiss.	
Arnold & Schaeffer Bwg. Co.	Philadelphia, Pa.	8	1500	....	40	....	Mica.	
U. S. Marine Hospital.....	Lewes, Del.	6	400	....	60	5	Clay and sand.	
Seitz Bros.	Easton, Pa.	6	250	....	40	....	Limestone.	
Chas. P. Williams..... ...	Stonington, Conn.	6	180	....	1			
Soldiers' Home	Kearney, N. J.	8	600	....	45			
Eckert Bros.....	Bridgeport, Conn.	8	300	20	75	....	Granite.	
D. Edgar.....	Norton, Conn.	8	800	300 ft. 8" casing; 500 ft. 5⅝" hole	1¼			
R. Hoe & Co..	New York City.	Two 8	50	....	One well 350; " " 100	....	Gravel.	
D. G. Yuengling Bwg. Co..	New York City.	8	600	100	65	....	Granite.	
Do. Do.	Do.	8	90	....	75	...	Gravel.	At 50 feet from surface perforation in pipe for upper water stratum.
Do. Do.	Do.	12	100	....	150	...	Do.	
Ballantine & Co.....	Newark, N. J.	8	450	80	200	....	Clay, sand, and red shale.	
Feigenspans Brewery.....	Newark, N. J.	10	480	80	250			
Lembeck & Betz.....	Jersey City, N J.	8	1500	100	25	....	Mica.	
Lexington, Mass.	Lexington, Mass.	8	150	10	125	....	Close textured granite.	

the drillings This form of drill is not popular with the well-driller for water supply, but is of great practical value to the geologist and mining engineer, as the core gives an exact section of the rock drilled. The architect is realizing the value of the diamond drill in making foundation soundings for the massive buildings erected in our large cities.

Many artesian wells have been drilled in this country, and the accompanying list of wells drilled by Messrs. P. H. & J. Conlon will give the reader an idea of what has been accomplished in this section of the country.

The art of drilling deep artesian wells of large diameter has been practically developed in the last few years, and with it artesian wells have become important factors as sources of water supply for both public and private use.

Where the water-bearing stratum is at great depth, wells of large diameter (8 to 12 inches) are drilled, because the diameter of a non-flowing artesian well determines its capacity, on account of limiting the size of the pumping machinery, capable of being operated in the well.

Where the water flows to the surface, or remains within practical suction distance while being pumped, the well can be sunk of a smaller diameter and still yield the same quantity of water as a non-flowing artesian well of much larger diameter.

In wells where the level of the water can be maintained at a practical suction distance and a large supply is demanded, it is at times the practice to connect a number of wells by horizontal piping on the surface of the ground, all leading to one suction pipe of a surface pump.

Sometimes an open well from 3 feet to 5 feet in diameter is dug from 10 to 60 feet deep, and in the bottom of this large well tube wells are driven, which allows a surface pump of large diameter to draw from the tube wells.

In wells where there can be maintained a sufficient head of water, the air lift is introduced with very good results, which by aerating the water in a discharge pipe, lessens its specific gravity. The water on the outside of the pipe and in the well acts on this lighter column and forces it out of the well.

Another method is to sink a well of a large enough diameter to lower a water cylinder, or working barrel, into the well, and operating the same by a steam cylinder, or by belting from shafting on the surface over the well.

COMMENCEMENT WEEK.

The exercises of Commencement Week of the class of '96 opened with the baccalaureate sermon, which was preached by Rev. George C. Houghton, D. D., at Trinity Church, Hoboken, on Sunday, June 14. Dr. Houghton delivered the sermon, in his usual eloquent and forcible manner, selecting for his text the following from Jeremiah xii. 2: "Thou hast planted them, yea, they have taken root; they grow, yea, they bring forth fruit."

He said in the course of his sermon:

"What is at the root of the church's teaching? Well, my young friends, it is just this—disposition. A merciful, forgiving, dutiful disposition to love God sincerely and keep His precepts; to ask His advice and help and to be grateful for His benefits. Such a disposition will lead you to worship and serve Him truly all the days of your life. Such a disposition will keep you natural in the world; in the business of the world; amid the pleasures as well as the buffeting of the world; yet with honor always as guide and elevation of mind and soul always the aim. I can think of no better advice to you for your future course in the world than this: Cultivate the disposition of Christ. Honor Him always and under all circumstances.

"You have passed through the years of your college life under exceptional guidance in the curriculum of your Alma Mater—the monogram S. I. T., which I have observed you wearing, stands for a great and favored endorsement in the working world. Your Alma Mater will look to see you wearing her signet not only with pride, but with honor—honor that will add still further lustre to her name. Let your advantages at Stevens serve you well in an upward and onward career of profit and usefulness to yourselves and fellows in the world, and mark you, my friends, I speak of an upward and onward career. You are just at your 'commencement.' You are

just at the opening of a world which is well stored—do not lose sight of that fact. Now you can commence your work of growth, and as you pass hence and your growth is accelerated, let it warn you against the temptations of sloth in your profession and also against the fascinating temptation to refer all practical growth to human agencies.

"Be it far from me to underrate human agencies, but while you advance in the knowledge of your chosen life-work and look up reverently to the great men and the result of their patient toil, do not set up for yourself an idol for worship. Never lose sight of the dutiful and humble reverence which you owe to Him who is the creator of nature which has in every case suggested the development of this great master mind."

The second day of Commencement Week was observed by the presentation to the Electrical Department of the Institute, by the class of '96, of a 5 horse-power Stanley-Kelly Induction Motor.

The presentation was made by Mr. William J. A. Boucher and the gift was received for the Institute by Dr. Geyer, representing President Morton, who was unavoidably absent.

In the evening of this day the class of '96 celebrated the destruction of calculus and, much to the disappointment of many, returned to the old custom of disposing of the monster by cremation rather than by the more modern process adopted by the class of '97—that of electrocution.

The procession, which was formed at 8.15 P. M., contained a large representation from each class. Dominos, masks, and torches were furnished to all who desired them, and a large quantity of fireworks was passed along the line. As usual, an immense crowd had gathered upon the campus to witness the ceremony.

After a short trial the condemned fiend was decapitated, placed in a coffin covered with cabalistic signs, and burned.

On Wednesday, June 17, from 4 to 7 P. M., President and Mrs. Morton tendered their annual reception to the faculty, alumni, and graduating class.

Owing to unfavorable weather many of the alumni were prevented from enjoying the pleasure of meeting President and Mrs. Morton, whose generous hospitality is one of the most pleasant features of Commencement Week.

The annual meeting of the Alumni Association was held in the Stevens School Hall, at 8 o'clock in the evening of this day. A full account of this meeting will be found elsewhere in this issue.

COMMENCEMENT EXERCISES.

The Commencement Exercises of the class of '96 were held at the Hoboken Theatre on Thursday, June 18, at 8 o'clock, in the presence of probably the largest audience that has ever gathered upon a similar occasion.

Upon the platform were seated, besides the Faculty and Graduating Class, Mr. S. B. Dod, President of the Board of Trustees, Mr. George W. Melville, Chief Engineer of the U. S. Navy, Mr. Robert W. Hunt, C. E., of Chicago, who delivered an address to the graduating class, Rev. George C. Houghton, Rector of Trinity Church, Hoboken, and Mr. Wm. B. Forbes, of Hoboken. The exercises were opened with prayer by Rev. George C. Houghton, D. D.

President Morton then delivered the following address:

Ladies and Gentlemen: In the old-time commencements, such as I attended as a student or graduate—when our chief studies were Homer and Hesiod, or Virgil, Horace and Ovid—a great deal was said about the original golden age of primitive man and how we had progressed downward through the age of silver and bronze to the sad age of iron.

Now, however, science has quite reversed this view, and we tell the story of human progress in another order, beginning with a stone age succeeded by a bronze age, and regard ourselves as having now advanced to an iron age, on our road to a golden age yet to come.

The world now moves very fast, and if I can trust the papers and the politicians, the age of gold may be at our doors, or, at best, no further off than St. Louis.

But, aside from that, we are at present conspicuously in an iron age, and, as iron is the staple of the mechanical engineer, in the age of the mechanical engineer and his works of iron.

We may, therefore, with good reason, congratulate ourselves that we are this evening sending out to aid the work of the age the largest class of well-equipped engineers that has ever left our walls, and we may indeed feel that in preparing them for their work we have contributed something towards the progress of our Nation and of free and enlightened institutions generally.

Nor is our contribution only to the material *progress* of our Nation; it is also to its *security*. Returning again to our early classical illustrations, we are reminded of the advice of the Delphic Oracle to the Athenians to trust for defense against a threatened invasion "wooden walls," which advice was followed and resulted in the never to be forgotten naval battle of Salamis.

Now as then the best defense of an invaded country is to be found in its ships, and it is especially brought to my mind by the presence with us this evening of Commodore Melville, Chief Engineer of our Navy, and substantially the creator of our White Squadron, that our safety lies largely in the hands of the engineers who have built, or are to build, and operate our iron ships of war. Indeed a modern naval battle is in fact a great engineering problem, in the solution of which, under Providence, victory will alight on the standard of the ablest and best equipped engineers.

Walter H. Dickerson delivered the salutatory address, which was as follows:

President, Gentlemen of the Faculty, and Board of Trustees of Stevens Institute of Technology, Friends and Classmates: Another cycle in the history of Stevens Institute has been completed, and another class goes forth from her halls to do battle with the world. Four years ago, this body of young men who appear before you, entered Stevens Institute as the class of '96, and to-night, they bid you welcome to the closing scene of their college career. After four long, yet all too short years of patient toil and study, we have at last reached the goal and are enabled to grasp the prize toward which our ambitious hearts and minds have so long looked forward.

That you have an interest in our success is shown by your presence, and we would indeed make ours the heartiest and most joyous of welcomes to show in a slight degree our appreciation of your encouraging words and interest taken in us in the past. Yet a sadness must of necessity be commingled with our joyous feelings over our success, for the curtain will soon be drawn upon the closing scene of our student life.

The associations of friendship which have existed in the past will now for the greater portion become severed and become memories. The walls of the old Stone Mill have resounded to our tread for the last time, and we must now bid "Farewell" to our Alma Mater.

But the happy days spent around the sombre walls of dear old Stevens can never be forgotten, but will ever exist as sweet memories of our lives.

And let us not forget those who were once among our number, but are absent to-night. Some were compelled because of ill health to seek other walks of life, and one, who had won the love and esteem of all his classmates, was called from us by the Great Teacher.

But, notwithstanding the fact that scarcely more than half of our original number are here to-night, the class of '96 comes forth from the Stevens Institute the largest by far yet graduated.

The degree we are about to have conferred upon us has ever been our guiding star. At first bright, but far distant, growing brighter and nearer as we progressed in our work, until now it rests upon us. As Freshmen, this event was looked forward to with fond hopes, but also with many doubts and misgivings, only partially realizing what lay before us, and the much coveted diploma appeared as a distant fairy castle, scarcely discernible, because of the clouds of work with which it was surrounded. But as the ordeals of each successive term were survived and the oft-dreaded examinations successfully passed, our hopes grew stronger, and doubts and misgivings gave way to confidence, until the last obstacle was surmounted, our position assured, and the diploma assumed a real form and now lies before us.

The old proverb, "No success without toil," has indeed been true with us. To-night has been reached only by diligent perseverance and untiring, unceasing effort.

Many have been the pleasures it has been necessary for us to forego; often have the midnight hours kept us at our work. Our desires, personal inclinations and feelings, in fact, all things have been subservient to this one object in view. Yet the prize is worthy of a noble effort, yea, a far nobler effort than we have been capable of. But let us not lose sight of the fact that it does not consist alone of the diploma which we are about to receive, and the degree which is about to be conferred upon us. These, indeed, should be highly valued, and our right to them should be most zealously vindicated by our future efforts, for they are the tangible proofs of our past four years of labor and are conferred by an institution without a peer. Nevertheless they are but the smaller portion The in-

sight into the laws and facts of Nature which have been given us, and the thinking and reasoning powers which have been developed in us, have possessed us of a wealth that none can gainsay, and a working capital the value of which is not to be estimated in dollars and cents. With such a foundation to build upon, have we not good ground upon which to feel confident of future success, and can we not rightfully expect, with the aid of Divine guidance, to rear a solid structure that in the future shall withstand the tempests of life's voyage?

Far be it from me, though, to picture a golden future where success should come with little effort and in which there were no mistakes, failures, and sorrows. Such a future does not and could not await us, but rather one fraught with hard work, in which true worth will receive its merited reward. True worth is shown by real results, which in turn bring success. If the record of the accomplishments of those who have preceded us through these halls of learning is to be taken as at all indicative of what awaits us, then is our confidence well founded.

And in such a noble profession we may well look for success. In the past, the genius of the engineer has played a most important part in the history of civilization, and it is destined to play an even more important part in the future. The scientist, inventor, and engineer have been the all-important factor in the world's progress and development. The scientist discovers and reveals the truths of Nature, while upon the engineer devolves the task of the development of these truths and their application to a practical purpose, for the advancement and betterment of humanity.

Franklin with his kite string drew the electric spark from the clouds, but to the genius of the engineer was left the development of that spark into useful channels, until to-day, electricity plays one of the most important parts in the history of the civilized world. By means of this unseen but potent power we are carried from place to place, our cities and homes are lighted, enormous power developed and transmitted to places of usefulness, and continents bound together and distance annihilated. Step by step from the crude model devised by Watt, the engineer has developed and perfected the powerful, massive, and beautiful engine of to-day.

From the little boat of Robert Fulton have gradually developed the swift liners and stately floating palaces.

From the primitive locomotive and train of Stevenson has developed the modern flyer. Perfection of material and mechanism, the result of the engineer's genius, have made these developments possible. The call of advancing civilization is for greater perfection and economy in all lines. (Swifter, cheaper, and more comfortable transportation in all its branches on both land and sea.) To accomplish these results in any small degree, lighter and stronger material and still greater perfection of mechanism are needed.

Into such a field of labor we are about to enter, perhaps in one branch, perhaps in another, in all of which, however, the teachings derived from experience and contact with the world are of utmost value. In this particular our instructors have most earnestly impressed upon us the teachings they have derived from many years of valuable experience. Also, in this profession, moral and mental integrity is of the greatest importance, the exercising of which has been comparatively easy heretofore, under the influences which have surrounded us, but now we are to separate from these influences and mingle with the world, where our integrity will often be sorely tried.

Most of us as yet have not realized the stern realities of life's battle, and we go forth to-morrow not knowing what is in store for us, perhaps overconfident, but withal possessed of a noble ambition and strong determination to win honorable success.

The first epoch in our lives is finished; the first turning point has been reached. To-night the world has a broader range of vision for us than ever before. As we look out upon the future, who shall say what is the destiny and what veriest ambition may not be realized! Why may there not develop from the ranks of "'96" a second Rankine, an Ericsson, an Edison, or a Roentgen? The future alone shall answer.

As water seeks its own level, so in life everyone sooner or later finds his own level. As is the man, so will be his position and sphere of usefulness. No task, however long, but has an end. To-night, by perseverance and honest effort, we have finished a long task, and thus will it ever be in the life which is before us; perseverance, with heart and soul in our labor, will eventually achieve honorable success.

In the years to come, as we are toiling onward and upward, and time shall engrave each record upon the pages of history, may

there appear opposite the name of every member of the class of "'96" with ever-increasing distinctness as the years roll by: "A successful life."

Then shall our motto "Through a rough road to the stars" indeed be true.

Mr. Robert W. Hunt next addressed the graduating class and was exceedingly interesting and entertaining. His remarks, which were in turn humorous and pathetic, had a most happy effect upon the audience.

He said in substance:

President Morton, Ladies and Gentlemen, Gentlemen of the Graduating Class: I presume you, gentlemen of the graduating class, feel that you should have come first in my salutation of this evening, and it is true that you are the heroes of the hour; but at the same time I venture to say that there are those present to-night who are if possible more interested in this successful culmination of your labors of the last four years than you yourselves; and with all the pride which you so justly feel, I venture that even greater pride animates the hearts and brightens the eyes of many of your audience —your mothers. I trust you are all blessed with a living mother's love, but if under the rulings of the All Powerful you have been deprived of her bodily presence, you have only the sooner attained a guardian angel. It is hard to believe that even Death, the seeming conqueror, can kill a mother's love. And let me urge upon you that if you will make it the guiding principle of your, I trust, busy and successful lives, to consider, before deciding upon important steps, what would mother say, you will be certain to never go very far wrong. I venture to say, and perhaps fear that it is true, that there are others whose bright glances are even more welcome to you to-night than those of your mothers; but it is right that it should be so; and let me urge upon you right here, that as soon as it is possible for you to offer a comfortable and honorable home to the right woman, do not hesitate to do it; it is the proper thing for you to work and strive for; and the chances are many to one in favor of its being the right woman rather than the right man. But of course I exclude the graduates of the Stevens Institute. When this right woman has consented to link her fortune with yours, be certain that you admit her to equal partnership. She deserves it, and you will find that your hands will be upheld by

letting her fully share your confidences. No matter how alluring a business proposition may appear, if you cannot submit it to her in all its baldness, do not hesitate to turn it down. If you will make your lives such that you feel confident they would have met with your mother's approval, and do meet with your wife's indorsement, you will never be afraid to be intimate with yourselves; and that is a luxury in which all the world cannot afford to indulge. Indeed I opine that some men who are pointed out as successful ones must avoid it very carefully. In fact I cannot imagine a much more dismal social function than they would find it.

But there are still others in your audience who are not to be ignored; and you must not treat them too cavalierly because they are only your sisters. Do not be too certain that the flash of their bright eyes is intended for you; it may be for the fellow who is sitting alongside of you. If not here, he may be on some other college platform; at all events he is somewhere, and when found, fortunately for the world, he will be to her a better man than you. Ladies, I assure you that it was in my mind to have expressed these sentiments before I read the St. Louis Republican platform. When you read it to-morrow, you will see that party is coquetting with woman as to her suffrage. For my part I cannot see, particularly considering that we have given the right to vote to almost everybody else, why we should not now let you have it.

Let me urge it upon you, young gentlemen, to go to work as soon as possible, and do not spend too long a time in picturing in your imaginations what your work should be; rather accept the first honorable position offered you; remembering that it has come down to us from ancient times that it is the man who makes the occupation, rather than the occupation the man; and when you do succeed in seeuring employment give to it your very best efforts, feeling the certainty that as you perform well that duty, greater ones are certain to offer themselves to you. I suppose you think you need a rest, but you don't, other, of course, than the summer's vacation that every workingman is entitled to. You will find in after life, that as hard as your labors of the last four years have seemed to you, they will appear light in comparison with the duties of your aggressively active life. Remember that you are already enrolled among the world's workers, and became so the first day that you entered school. Of course your work has been that of

training. No commander would desire to meet the enemy with untrained troops, although, of course, there have been instances when, in such encounters, they have been successful; but as the art of war has progressed, so have the chances of such success decreased, and so each year renders it more difficult for the uneducated man to attain great success. It is true that the lives of many uneducated but successful men can be instanced, but though true, how much greater might have been their success, and certainly how much easier it would have been to them had they been equipped as you are. I repeat my advice to you: seize the first opportunity for employment. During a busy life I have constantly observed how much easier it is for an employed man to go from one situation to another rather than for an unemployed one to obtain a situation of any kind.

President Morton, I congratulate you. As one of the Trustees of the oldest technical school in America—the Rensselaer Polytechnic Institute—it gives me pleasure to congratulate you, and through you the Stevens Institute, and all who are interested in it, in this graduation of the largest class in its history. As to its quality—the brain of the class—that speaks for itself. Young gentlemen, God bless and prosper you; ladies and gentlemen, I thank you.

Mr. S. B. Dod, President of the Board of Trustees, then conferred the Degree of Mechanical Engineer upon the members of the class of '96, having previously handed each member a diploma of graduation.

He also announced that the Stevens School Scholarship had been awarded to Marvin Shiebler, and the Priestley Prize, for excellence of work in the Department of Chemistry, to Henry Donald Tieman, '97. In addition to the latter award the work of Wm. F. Doughty, Wm. D. Ennis, Gordon L. Hutchins, and Paul S. Whitman received honorable mention. Mr. Dod also made a special announcement to the effect that the Board of Trustees not only recognized meritorious work executed within the walls of the Stevens Institute, but also appreciated superior engineering ability outside their institution.

They have at the present time recognized a claim to distinction in the services rendered by one who is well known as the commander of the Jeannette Expedition, and who in this capacity, by

his indomitable courage was able to infuse enough energy into his famished crew to carry them over 500 miles of snow and ice.

He then announced that the Degree of Doctor of Engineering had been conferred by the Board of Trustees upon Commodore George W. Melville, Chief Engineer of the U. S. Navy.

The announcement was received with much applause, and in accepting the diploma handed to him, Mr. Melville said that he remembered every instance of promotion since his boyhood, but no event of his life was regarded with as much pleasure and appreciation as the honor which had just been conferred upon him.

The valedictory address was then delivered by Arthur J. Wood It was as follows:

VALEDICTORY ADDRESS.

Mr. President, Gentlemen of the Board of Trustees, Members of the Faculty, Fellow Students, Friends: The class of '96 desires to leave a few parting thoughts. To some who have honored us by their presence to-night these closing words may seem to be the mere repetition of a custom more or less common on occasions similar to this. To us, and our friends who have eagerly watched our progress for four years, it has a deep significance. The last link in the golden chain binding sixty-four college-bred youth to their life-work has been welded, and we are about to go forth and test those links to see if they will serve us in all the vicissitudes of life. The dream of the past has become the realization of the present. The fond anticipations of those who have shared with us our pleasures and sacrifices were to-night fulfilled as we received the long-sought-for degree. It is appropriate, then, that we should pause at the threshold of professional life to recount the privileges of the past and consider the blessings of the present

We step forth to life's activities in one of the closing years of the nineteenth century. The walls of prejudice that once would impede our progress have been overthrown by the honored graduates of this and kindred institutions. In every department of science there is a universal interest, so that the progress on one side of the globe keeps pace with the advancement on the other. New mines of intellectual wealth are every year being opened, and all nations are coming to share more and more the fruits of knowledge. Truly the inheritance of the past is ours. But the greater the opportunities the brighter the prospects, and

the more the public takes an interest in technical education the more thorough must be our training.

The engineering problems with which we will deal are not those found in books. We are equipped as the military engineer who does not fight a single battle according to fixed rules, but who imbibes certain principles from books which are to govern his tactics. The battles in engineering have not all been fought, else we would have little to look forward to, and if we would be successful in our chosen profession we must join theory and practice. The union of the mechanic and the man of science, and the fruit of that union, the engineer, so rarely seen in the olden times, has become as common as the practitioner of medicine or surgery. To those who have sought to instill into our lives the principles on which we must rely if we would succeed, we owe a debt of gratitude that words fail to express.

Esteemed President: If we should dip our pen to-night in the sunlight of unbiased expressions of gratitude to you and write them in flaming letters, they would reflect the sincere esteem of every member of our class. Mere forms of expressions are meaningless, and we know that you would rather have us become true sons of Stevens in the future than to listen to words of encomium to-night. Were it possible, however, we would place new laurels on your brow. By the natural force of character, by uniform kindness and unerring discriminations between questions of right and wrong, you have won the highest respect of the largest class ever graduated from the Stevens Institute of Technology. The ever increasing facilities for more thorough instruction in the course which the trustees under your wise guidance have provided for us is another proof of your unswerving devotion for the institution you have molded and an evidence of your faith in what it may yet accomplish. With hearty thanks we bid you farewell.

Members of the Faculty: You have guided another group of engineering students to that stage where each must feel for himself the responsibilities of life. Other voices will be heard in the classrooms and on the campus; others will be honored by diplomas bearing your signatures. As year by year the list of graduates grows larger, the voices of those who will praise you for your devotion will go on increasing. We would assure you that your efforts in our behalf will never be forgotten, the thoughts and inspirations emanating

from you will never perish. "To live in the hearts we leave behind is not to die."

Many times have we seen and heard you as towering intellectual giants, at once broad and strong; many-sided in learning and culture; philosophical at once and practical; lovers of science, but not isolated from the world; profound in study, yet influential among mankind. Your fame is world-wide. We are proud to have known you and to have had our lives molded by your influence. Five and twenty years have rapidly passed away, and who can measure the effect your efforts have had on higher engineering education? The first quarter of a century of the Institute's existence is closing; every member, save one, of the original faculty has continued with us to the present. It is our parting wish that years of appreciated usefulness may yet be yours within the famous walls of Stevens.

Men of '96; Classmates: The springtime of our lives is over; the summer has begun and there is promise of an abundant harvest. Life has become real and the struggle may prove to be a hard one. To us, this is the age of ambition, striving for home, wealth, knowledge, and honors with a dogged determination to press on until something yields. If we have aimed at nothing there will some day be a rude awakening from bright dreams and life will be stripped of its flashing colors. But we cannot fail with a clear purpose in view and with loving hearts that will stand by when tempest-tossed and swell with joy when we triumph over difficulties. Let us remember that success is mostly a matter of devotion, and the more complete the devotion the greater the success; or in other words, "He that loseth his life shall find it." Every great and commanding movement in the annals of the world is dependent upon devotion We have entered a noble profession, one in which sophistry and deception cannot long predominate. Nature's laws must guide our actions and to seek to evade these laws is to challenge the Divine will. Though none of us may achieve greatness, all may win an honored place in the world if we inculcate into our lives manly principles. Questions of capital and labor, of social status and industrial economics will command a share of our thought, but life's greatest mission, after all, is in drawing aside the curtain and permitting some rays of Divine sunshine to dispel the darkness of ignorance and to cause what was the cup of bitterness to overflow with joy.

The ceaseless river of time has brought us to the wide sea of life. Many embarked with us four years ago who are not here to-night. Some lost courage and drifted before the wind, some sought other channels, and one of our number, whose memory we cherish, sank beneath the waters and his voice is forever hushed. Those of us who are left of the original one hundred and seven must now separate, each to take his own course on the pathless sea before us. With deep emotion we grasp each other by the hand as we bid the friends of college days a hearty godspeed, and go forth. When on life's open sea, breasting the waves, our barks chance to meet, the renewal of friendships of the past will kindle afresh the undaunted purposes of to-night, and with increased courage we will fight manfully on amid life's troubled waters as the rolling sea bears us on to the great harbor of eternal rest to bask forever in the sunlight of God.

The exercises closed with the benediction, pronounced by Rev. Geo. C. Houghton.

With the usual complement of music by the orchestra these exercises were declared to have been as successful as any heretofore held.

The class of '96 graduated 64 members, which is 19 more than have been graduated in any previous year.

A list of the graduates and their theses are given herewith:

JOHN P. BADENHAUSEN.
Experimental Determination of the Velocity of the "Pelton" Wheel for Maximum Efficiency.

HARDING BENEDICT. GEORGE HEWITT. ROBERT LEBER.
Experiments to Determine the Economy of Operating a Non-Condensing Steam Engine with a Mixture of Steam and Compressed Air.

HARRY T. BERNHARD, JR. LEONARD SEELIGSBERG.
Test of the Electric Plant of the Hoboken Quartette Club

WALTER H. DICKERSON. L. J. BORLAND.
Review of the "Hardie" Compressed-Air Motor.

WM. J. A. BOUCHER. S F. BUTTERWORTH.
Test of the Generating Plant of the Jersey City, Hoboken, and Rutherford Electric Railway.

PH E. BRUCKNER. MARTIN SHEPARD. JOHN SCHIMMEL, JR.
Calorific Power of Gases by "Junker" Calorimeter.

BRADFORD BUMSTED. THEODORE F. HUSSA.
Test of Brunswick Traction Power Company's Plant.

E. E. BURNET. EDWARD CAMPBELL,
The Permeability of Solutions of Iron, Nickel, and Cobalt.

DOUGLAS S. BUSHNELL. J. B. FAULKS, JR. WALDO E. DENTON.
Test of Alcohol Vapor Engine.

J. L. CHRISTY. S. AUGUSTUS HASBROUCK.
Determination of Cost of Electric Lighting by a Gas Engine.

BAYLIES C. CLARK. CHARLES H. HUNT.
Comparison of the Transmitting Power of Pulleys of Different Surfaces.

CHARLES F. COLLYER. CHARLES B. PECK.
Economy and Efficiency Test of Hornsby-Akroyd "Patent Safety" Oil Engine.

EDWIN L. DECKER. OLIVER A. POPE. P. D. WAGONER.
Review and Test of the Plant of the Cataract Construction Co. at Niagara Falls, N. Y.

JOHN P. EVERTSZ. CELESTINO GARCIA. HENRY GUTTIN.
Review of the Power Plant of the Reading Terminal, Philadelphia, Pa., Including Tests of Boilers with Different Coals, of Refrigerating Plant and Air Compressor.

H. M. HARDIE. L. H. HARDIE. FREDERIC R. HARRIS.
Review of the Ventilating Plant of the Surgical Buildings of the Presbyterian Hospital, Seventy-first Street and Fourth Avenue, New York City.

ALBERT W. GUNNISON. W. H. JENNINGS, JR.
Economy Test of 150 H. P. High Pressure Engine with Corliss Valve Gear and Shaft Governor.

SAMUEL HOLLINGSWORTH.
Test of a Worthington Compound Duplex Pumping Engine.

T. W. JOHNSON. ARTHUR J. WOOD.
Efficiency and Capacity Test of a "Rife" Hydraulic Ram, and Comparison of the Effect of "Statical" and "Sliding" Head in Driving the Ram.

JOHN P. KENNEDY. CARROLL MILLER.
The Practical Efficiency of Illuminants.

R. T. KINGSFORD. WM. H. MACGREGOR.
Test of the H. Ward Leonard Electric Elevator in Fahy's Building, Maiden Lane, New York City.

GEORGE KOLLSTEDE. WM. C. MORRIS.
Test of the Water Consumption of a "Case No. 5D" Engine.

JOHN B. KREISCHER. WALLACE WILLETT.
Test of a Wright Corliss Engine and Boilers in a Brick Manufactory, and the Determination of the Power Required to Drive Different Combinations of the Machines.

WM. C. MAUL. F. F. OVERTON. HARRY S. SUMMERHAYES.
A Comparison Under Different Loads of a Corliss (belted) and a High Speed (direct-connected) Engine in the Electric Lighting Plant of the Metropolitan Life Insurance Building, New York City.

HILLARY C. MESSIMER.
Commercial Efficiency Test of the Hecla Air-Compressing Plant of the Calumet and Hecla Mining Company.

W. B. OSBORN. ARTHUR C. WOODWARD. FRANK PLUM.
Calorific Power of Coal and of the Permanent Gases which Appear on Distillation at Low Temperatures.

WILLIAM T. RASMUS. ALLEN E. WHITMAN.
Comparative Test of the "Almy" Water Tube Boiler, at W. D. Forbes & Co.'s Shop, Hoboken, N. J.

W. J. RUSLING, JR. CLIFFORD G. WOOLSON.
Test of a Raymond Improved 30 H.-P. Double Cylinder Gas Engine and Dynamo.

M. V. G. SMITH. EDWARD M. TOBY. W. R. WILSON.
Comparative Test of Compound, Duplex, Direct Acting "Snow" Pump, at Different Speeds, Located at Montclair, N. J.

JAMES H. STEARNS.
Determination of Power Required to Drive Hydro-Extractors with Corliss Engine.

MAX J. WEICHERT.
Comparison of Volumetric and Gravimetric Methods for the Determination of Carbon in Iron and Steel.

MEETING OF THE ALUMNI ASSOCIATION.

PRESIDENT H. DE B. PARSONS called the meeting to order at 8.45 P. M., a quorum being then present.

The minutes of the last meeting were approved as printed in the INDICATOR, their reading being dispensed with.

The Treasurer, Wm. H. Bristol, made the following report:

TREASURER'S REPORT.

HOBOKEN, June 17, 1896.

To the Alumni Association of the Stevens Institute of Technology:

I.—GENERAL FUND.

Receipts.

Balance in Fund June 19, 1895	$6.62	
Dues for 1895-96	980.00	
Dues for arrears	262.50	
Dues in advance	12.50	
		$1,261.62

Expenditures.

Alumni subscriptions to STEVENS INDICATOR to June, 1896—443 at $1.50	$664.50	
P. E. Raqué, Corresponding Secretary, printing, postage, and clerk hire	81.19	
F. D. Furman, Corresponding Secretary, printing, postage, and clerk hire	64.13	
W. H. Bristol, Treasurer, printing, postage, and clerk hire	40.88	
Expenses, annual meeting, June 19, 1895	4.00	
Expenses, midwinter meeting, February 19, 1896	180.50	
Moving safe	3.50	
		$988.70
Balance on hand June 17, 1896		$272.92
Dues in arrears June 17, 1896		387.50

II.—BENEFICIARY FUND.

Receipts.

Balance on hand June 19, 1895	$332.57	
On loans repaid	82.96	
Interest on loan	4.82	
Bank interest to January 1, 1896	9.43	
		$429.78

Expenditures.

Loan		50.00
Balance on hand June 17, 1896		$379.78
Amount of outstanding loans, including temporary loan of $600 to STEVENS INDICATOR		$1,192.23

III —LIBRARY FUND.

Receipts.

Balance in Fund June 19, 1895	$114.75	
Interest (bank) January 1, 1895, to January 1, 1896	4.59	
		$119.34
Balance in Fund June 17, 1896		119.34

IV.—LIBRARY PORTRAIT FUND.

Balance in Fund June 19, 1895	$1.72
Balance in Fund June 17, 1896	1.72

V.—STEVENS INDICATOR.

Receipts.

Balance on hand June 19, 1895	$1.71	
From Prof. Graydon, Business Manager	383.93	
From Prof. Riesenberger, Business Manager	660.58	
Alumni subscriptions to date	664.50	
		$1,710.72

Expenditures.

Copies of INDICATORS (back numbers)	$8.50	
Binding INDICATORS	4.40	
Publication July INDICATOR, 1895	236.20	
" October " 1895	180.80	
" January " 1896	307.22	
" April " 1896	366.54	
Prof. Graydon, editing July and October INDICATORS	100.00	
Prof. Riesenberger, editing January and April INDICATORS	50.00	
Prof. Stillman, editing January and April INDICATORS	50.00	
Drawings and cuts for INDICATOR	59.44	
Stationery	14.75	
Envelopes for mailing INDICATORS	13.68	
Balance on bill printing—Simpson & Lyall	6.75	
		$1,398.28
Balance on hand June 17, 1896		$312.44

Respectfully submitted,

W. H. BRISTOL, Treasurer.

ROBT. C. OLIPHANT.
F. D. FURMAN. } Auditors.

On motion the Treasurer's report was accepted.

The Executive Committee then submitted its report, which was as follows:

Your committee have to report that they have had the number of meetings prescribed by the Constitution, and that they are glad to say that these meetings have been well attended.

Acting upon instruction, issued at the last annual meeting of this Association, that the matter of the loan to W. W. Thomas, '86, be further investigated, a committee consisting of Messrs. Riesenberger, Bristol, and Torrance was appointed.

This committee reported at the April meeting of the Executive Committee to the effect that they had used all the means at their command and that they had been unable to get any expression from Thomas acknowledging his obligation. The Executive Committee now present this matter to you for final action.

Your committee have to report the resignation of Prof. Graydon as Editor of the INDICATOR, and the appointment of Prof. Riesenberger and Dr. Stillman as co-Editors.

The resignation of Mr. P. E. Raqué as Corresponding Secretary was received and accepted and Mr. F. D. Furman was appointed in his place.

The committee have further to report that through the kindness of Professor Graydon they have secured the loan of a safe for the use of the Association.

At the January meeting of your committee the Treasurer reported that the sum of $600 was owing the Association for dues, and asked for some method by which the members in arrears should be made to either pay their dues or to send in their resignations. The following resolution, which has appeared in the INDICATOR, was passed:

"*Resolved*, That the Treasurer be authorized to insert in the July number of the INDICATOR, each year, the names of all members of the Alumni Association who are in arrears for dues for a period of one year or more, provided the proper notices as called for by the Constitution shall have been mailed to their addresses, and that a notice to this effect shall have been sent with the last notice."

The Treasurer's report shows the result of this resolution.

Your committee consisting of Messrs. Van Atta, Torrance, and Riesenberger, appointed by the Executive Committee to co-operate

with President Morton and the committee of undergraduates to make up a program, etc. for the twenty-fifth anniversary of the Institute, report the following program:

PROPOSED PROGRAM OF EVENTS TO COMPRISE THE CELEBRATION OF THE TWENTY-FIFTH ANNIVERSARY OF THE STEVENS INSTITUTE OF TECHNOLOGY.

Thursday, October 29, 1896.

ATHLETIC GAMES:

Freshmen vs. Sophomores, three contests.....9 A. M.
Alumni vs. Undergraduates, football match.....3 P. M.

SMOKER:

Quartette Club Hall, Hoboken.....8 P. M.

Entertainment by Musical Clubs of the Institute, assisted by individual alumni.

Collation.

Friday, October 30, 1896.

RECEPTION AT THE INSTITUTE.....2 to 6 P. M.

To Invited Guests, Faculty, Alumni, and Undergraduates.

From 2 to 6 o'clock P. M. the Institute is to be thrown open for the inspection of visitors, and a collation served in the Institute Building from 4 to 6 P. M.

GRAND BANQUET.....8 P. M., New York City.

Participants: Trustees, Faculty, Alumni, Undergraduates, and Invited Guests. The latter to include, among others, the Governor of New Jersey and the Presidents of the principal Technical Schools.

Estimated cost per plate, $5.

It is also proposed that a Guarantee Fund of not less than $500 be raised to defray expenses of the celebration and of the publication of a *Memorial Volume* to contain an account of the celebration.

The following members are suggested for the Committee of Alumni who, in conjunction with a committee of the Under-

graduates and of the Faculty and Trustees, shall make all arrangements for carrying out program to be adopted:

PRESIDENT OF THE ALUMNI ASSOCIATION.
ALEX. C. HUMPHREYS.
WM. H. BRISTOL.
J. H. CUNTZ.
H. DE B. PARSONS.
JOSEPH WETZLER.

Your committee report the following resignation of members in good standing: David Corbin, '94; Kinsley L. Martin, '92; G. W. Merritt, '91; Phillip Wallis, '79; Jas. H. Scott, '89.

The report of the Executive Committee was ordered spread upon the minutes by the President.

The Recording Secretary read the following report submitted by the Trustees of the Alumni Building Fund:

HOBOKEN, N. J., June 17, 1896.

To the Members of the Stevens Institute Alumni Association.

GENTLEMEN: We beg to make the following report relative to the Alumni Building Fund:

Amount received from all sources to June 1, 1896	$13,400.81
Amount in Fund June 1, 1895	11 819.24
Increase for year	$2.081.57

This increase of $2,081.57 for the year ending June 1, 1896, has been received from the following sources:

Interest on $20,000 bonds (contribution of President Morton)		$1,000.00
Interest on invested funds		460.00
One-half proceeds of Chickering Hall concert		200.00
Subscriptions paid		216.42
New contributions	Alex. C. Humphreys, '81	100.00
	Wm. H. Bristol, '84	100.00
Miscellaneous		5.15
Total		$2,081.57

Including the accrued interest, the total amount of the Fund June 1, 1896, is $14,127.01

Respectfully submitted,

HENRY MORTON.
A. RIESENBERGER.
Trustees of Fund.

Upon motion this report was accepted. Frank H. Coyne, '94, and the members of the class of '96 were elected to full membership in the Association, and B. C. Ball, '95, to associate membership.

President Parsons then delivered the following address:

"FELLOW ALUMNI: Another year has rolled away and with it ends my tenure of office as President of your Association, and as I stand ready to surrender my chair to a more worthy successor, it becomes me, in compliance with our usual custom, to make a short address. Before doing so, however, I wish to take this opportunity of expressing to you all my most sincere thanks for the honor which you conferred a year ago in selecting me as your presiding officer, and I trust that my deeds and actions while in office have always met with your unanimous approval. It should be deemed no idle honor to be elected President of the Alumni Association of Stevens Institute, and each and every graduate and undergraduate should look forward to the time when he may be the one selected for that position. Owing, however, to the nature of our organization, it is impossible for every one to be fortunate enough to be chosen, but that knowledge should make the members strive the harder in order to receive the honor. In saying this, I do not mean, nor do I think it would be wise, for each one of us to struggle with that object directly in view; but I do mean that it would be a great benefit to the Association if each of its members should have the proper ambition and longing to serve his Association in the capacity of President. The office carries with it no idle honor, and unfortunately there is more work connected with the office than the incumbents are usually able to fulfill. What, however, has been true of the past is not necessarily true of the future.

I stand before you to-night as the retiring President, the last to hold the office during the first quarter of the century of our existence, and my successor will pick up the reins of government as the first to enter into the new period.

It has been customary each year for you to listen to a presidential address more or less filled with the greatness of our Association, its strength, its advantages, and the growing popularity of our Alma Mater. I propose not to follow in the footsteps of my predecessors, for I believe that you all, as individuals, are just as well aware of our greatness as the members of your Executive

Committee, and I purpose, therefore, to touch upon other matters and briefly sketch some of the facts which to me appear as in the direction towards which we should strive for future advancement. There is an old business saying, and one that is certainly very true, that when one balances his book at the end of the fiscal year the record should be made not to show how rich that person may be, but rather how poor he is. As what I may say is of course my own personal opinion, it cannot be taken as either binding on the Association or even as expressing the sentiment of your Board of Trustees. In the first place, our Association is made up of individuals, and in order to be strong, so as to carry out the purposes for which it was organized, it is essential that there should be complete concert among its members. All our actions should be governed by the motto of the Belgians, '*La union fait la force.*' During the past year I have spoken to some of the graduates of our Institute who not only expressed lack of love for their college, but actually gave utterance to feelings very much the reverse. While such men are bound to exist, on account of the great diversity of human nature, it should be our business and our policy to prevent the spread of any such sentiment, and to do our best to unite those individuals and bring them back within the fold of those who love, honor, and cherish the mother that gave them their degree with which to fight the battles of life. Every graduate of the Institute should be a member of our Association, but I cannot indorse the policy of electing the graduating class as a body, and in that way receiving within our ranks, some that may not come in willingly and voluntarily of their own free will. I believe that it would be much better policy if the custom were once established, for each member of the Senior Class to make application and be elected in the usual manner of associations similar to our own. The objects of our Association are sufficiently worthy to attract to its membership all that may graduate from these halls, and there should be no urging on our part. The object of our Association is not only to institute good fellowship among its members, but also to lend such aid and give such advice to those who manage the affairs of our Alma Mater, as to assist them in the great work which they are carrying out. Furthermore, the fact that each membership carries with it an annual subscription to the INDICATOR, a publication which is certainly worth the amount of the annual dues, should be

enough inducement to those who truly love the halls that assisted them when they were young.

During the past twenty-four years the Institute has graduated about five hundred members, and of these five hundred, only about four hundred have been enrolled in our Association. Further, that of those whose names are carried on our books, but a still smaller fraction pay their annual dues. If a man does not care to remain a member he certainly should resign, because such is the only way which will permit the managers of the Association to know in advance what annual revenue may be expected. Many schemes have been proposed with the object of reducing this delinquent list to a minimum, but none of those that have been put into practice has ever proved to be sufficiently stringent to serve the purpose for which they were designed. Your officers are now trying a new plan, which promises well. The only strong opposition has been from members in arrears. It is my belief that your Association would be stronger without them than with such names on the roll. The Association is in no sense one of charity, and the yearly dues should not be paid with any such erroneous impression.

During the year I proposed a scheme to introduce a course of outside lectures for the benefit of the undergraduates. It was my intention that these lectures should be under the direction of the Faculty, but that they should be held at times convenient to the alumni, so that a full attendance might be expected. After having made my proposition, I noticed in a belated number of the INDICATOR that our fellow member, Mr. Wolff, had proposed the same general scheme. I make this acknowledgment, as I do not wish it thought that I was attempting to undertake Mr. Wolff's idea in my own name. My scheme, however, was considerably broader and more comprehensive than that outlined in Mr. Wolff's letter. I proposed that a series of lectures be given from time to time on the subject of bookkeeping, banking, investments, patent law, laws of contracts, and specifications. These subjects are not touched upon during the regular four years' course, although they are subjects of vital interest to the practicing engineer. Few of the students have opportunity of becoming posted on these subjects previous to their entrance into the field of actual work. It appeared to me that the Institute could get the very best men to lecture on these subjects without expense, provided they were only given

sufficient time in which to prepare. I was gratified to receive an invitation to attend the first of these lectures on 'Patent Law,' and to feel that work in this direction has actually been undertaken.

Probably most of the students, and perhaps many of the alumni, do not appreciate the advantage that would accrue by listening to discussions on these topics. My idea was not to give a full course, as that would take too long, but simply to have the subjects so discussed as to draw the attention of the listeners to the fact that there were such things in existence. For instance, that economy can be improved by a proper system of bookkeeping, especially in connection with large manufacturing establishments, operating different departments; that the binding clause and that the penalty clause as usually written in specifications are not legally enforcible; and that often the general clause is of such a character as to render the contract, when signed, unfair to one or the other of the contracting parties. To illustrate the point at issue, I was informed that a certain graduate of the Institute contracted with a certain town to build and operate an electric trolley road, and that as one of the conditions for granting the franchise the specifications stated that the streets of the town should be repaved in the most approved manner. I do not know the name of the alumnus, nor do I know the name of the town, and I therefore feel that I am at perfect liberty to mention the incident.

When the road was completed, the town declined to accept the work, because the streets were not properly paved, claiming that under the contract, the new pavement should extend from gutter to gutter, and demanded a system of pavement which was far in excess of the necessities of the case. The contractor, who had written the specifications himself, only intended and only figured on repaving between the tracks, as is generally understood in such work. To repave the streets occupied by his road would require more money than the company could afford to pay. Had such an alumnus had the benefit of listening either as an undergraduate or as a graduate to a lecture on the laws of contracts and on specifications, I hardly think he would have made such a fatal error against his own interest. It must be remembered that the financial side of engineering is always the most important, and that the sooner the young engineer recedes from the idea that simply because he is a professional man, perhaps with the title of

"chief," that his position is paramount, the better will it be for him. He must be always subservient to those who represent the money invested in the enterprise. Lectures, therefore, on banking and on investments, I believe, would be of the very greatest benefit. In mentioning this subject, I feel that the assistance of the Alumni would be of great value to the Faculty and that it should be the duty of the Board of Trustees of your Association to co-operate with them for the benefit of all.

I appointed during the year a special committee to report on the best means of increasing the Beneficiary Fund, the Building Fund, and on such improvements in the curriculum of the Institute as they might deem best. This committee reported that the time was not ripe to undertake any such work. With that report I personally cannot concur. No one realizes better than myself the hard times through which the country is now passing, but we should never forget the old business saying, 'that the time to buy is when others are selling, and that the time to sell is when others are buying.' I believe, therefore, that it would have been best to have occupied our time during these dull months in perfecting some plans to advance the objects just mentioned; and then, when general improvement should return to our business centers, our plans would be ready, and there would be no delay in placing in operation whatever scheme might have been proposed.

The Beneficiary Fund is operating in a most successful manner, but the good work which it does is not always known by the members of the Alumni. The Building Fund is growing slowly, but not so rapidly as it should, and although the Trustees of your Association undertook to assist it by giving an entertainment, the entertainment was so badly attended that the object was practically a failure. If we are to succeed, we surely must work in unison, and the appeals, in whatever form they may take, that are officially sent out by your Board of Trustees, should be answered not only by individual support, but with the idea that a collection of individuals means strength.

There is only one other feature about which I would like to speak, and that is in regard to the proposition made by Mr. Alexander C. Humphreys at the midwinter meeting. It would undoubtedly be of the greatest benefit to our Alma Mater if it were possible to institute a retiring fund, the interest of which could be used to

pension the members of the Faculty when their term of usefulness has ceased. This, however, is a subject of such great importance, on account of the large sum that it would be necessary to raise, as to require the most careful attention and thought. As the Institute stands to-day, it should not, in my opinion, be pressed forward in any manner that would injure the efforts made to increase the Building Fund, but I can most heartily indorse the scheme and most respectfully bespeak for it the attention of the new Board of Trustees.

In closing I desire to again call your attention to the fact that your Association is not founded for any idle purpose. It remains entirely with you to so transact your business as to make the Association most powerful along the lines upon which it was originally intended it should operate.

Give it, therefore, Fellow Alumni, your most earnest attention, and I feel sure that you will soon see the fruit of your labors in the ever increasing love for your organization."

Upon a motion it was ordered that a committee to be appointed by the chair report at the next meeting on the advisability of incorporating the Association.

A lengthy discussion followed upon the action of the Executive Committee ordering a list of the members who are in arrears for dues to be inserted in the July INDICATOR.

It was finally upon motion agreed that the Treasurer send the list of delinquents with the December bills instead of publishing the list in the July INDICATOR.

On motion the Association tendered a vote of thanks to Dr. Stillman and Professor Riesenberger for the good work they have done on the INDICATOR.

The Recording Secretary then reported the result of the balloting for officers for the ensuing year and for Directors and Alumni Trustee, which was as follows:

PRESIDENT.

E. P. Roberts, '77 57
F. C. Jones, '78 14
J. W. Lieb, Jr., '80 41
Jos. Wetzler, '82 35

1st VICE-PRESIDENT.

Anson W. Burchard, '85.....102
Robert C. Oliphant, '89..... 44

2d VICE-PRESIDENT.

Robert M. Dixon, '81.....111
W. S. Ackerman, '91..... 34

CORRESPONDING SECRETARY.

F. D. Furman, '93.....147

RECORDING SECRETARY.

J. Day Flack, '87.....131
David Gildersleeve, Jr, '89..... 15

TREASURER.

William H. Bristol, '84.....148

DIRECTORS.

P. E. Raqué, '76.....103
E. A. Uehling, '77..... 92
E. P. Mowton, '86..... 48
A. S. Miller, '88..... 52

ALUMNI TRUSTEE.

J. W. Lieb, Jr., '80..... 46
Harry Van Atta, '81..... 34
H. de B. Parsons, '84..... 53

The officers of the Association for 1896-97 and the four directors who will constitute the Executive Committee for the ensuing year, will therefore be:

President, E. P. Roberts, '77.
1st Vice-President, Anson W. Burchard, '85.
2d Vice-President, Robert M. Dixon, '81.
Corresponding Secretary, F. D. Furman, '93.
Recording Secretary, J. Day Flack, '87.
Treasurer, William H. Bristol, '84.
Directors, P. E. Raqué, '76, E. A. Uehling, '77, A. Riesenberger, '76, K. Torrance, '84.

Durand Woodman, retiring Alumni Trustee, made the following report:

REPORT OF ALUMNI TRUSTEE.

"After the manner of the retiring President, it seems to have become customary for the retiring member of the Alumni Trustees to

make a report in behalf of the Trustees. I therefore have the honor of reporting to you a few facts in regard to our welfare and plans.

In respect to the number of students the Institute has held its own during the past year. In fact the actual number in attendance has been rather larger than ever before, notwithstanding that the entering class was a little smaller. The average number per class has been larger. The graduating class is the largest that has ever left our walls, and it is whispered that it is one of the best.

Our financial condition is sound in that we are not in debt, nor borrowing money, but a wider margin of security would be appreciated and is much to be desired in view of the more general competition which has to be met each year.

The graduating class has presented the Institute with a five horse-power Stanley–Kelly induction motor.

The class has also presented to the Physical Laboratory a large and fine balance, which is not only sensitive, but is capable of carrying large loads.

The Board of Trustees has voted to add Mr. Richard Stevens to their number; to also confer the degree of Doctor of Engineering on George W. Melville, Chief Engineer of the U. S. Navy, Washington, D. C.

A committee of the Trustees has been appointed to act with the Alumni and Undergraduates in the matter of the proposed twenty-fifth anniversary celebration in October. President Morton, Alex. C. Humphreys and F. E. Idell constitute the committee.

The Trustees have decided that a series of lectures shall be delivered next year on Business Methods, including Double Entry Bookkeeping.

The lectures on Patent Law last winter were considered a success.

Mr. H. de B. Parsons has been elected Alumni Trustee for three years."

Upon the invitation of the Chairman, President Morton addressed the meeting.

He said: "It gives me pleasure once more to receive the encouragement implied in the presence to-night of so many of our graduates, evincing as this does your lively and unflagging interest in the affairs of your Alma Mater. As to the history of the last

year, this has been so well given by Dr. Woodman, the retiring Alumni Trustee, that I could only repeat what he has already said on this subject. Indeed, to my case clearly applies the Spanish proverb, "Speech is silver, silence is golden." In this connection let me, however, remark that in certain recent political relations it has been somewhat doubtful whether silence was silver or golden.

"However, as far as the Institute is concerned, our quiet or silent progress has involved a sufficiency of silver and gold to make two ends meet, with a little margin, which I would gladly see increased, but which, at all events, keeps us within the limits of safety, for which we should be especially thankful, in view of the difficulties which have crippled so many of our sister institutions.

"We may then look forward hopefully to the other quarter-century which opens next fall, and which, as you have just heard, it is proposed to celebrate. In that connection let me announce that at the last meeting of the Trustees a committee was appointed to act with the Alumni and Undergraduates in conductiug the proposed celebration, with power to expend $300 if necessary. In the report of your Executive Committee I notice the securing of a guarantee fund of $500 to meet expenses of the celebration.

"This authorization of the Trustees may be regarded as representing a guarantee of $300, and as I will guarantee $200, that matter may be considered as settled, though I do not, by any means, wish to discourage anyone who may wish to add to the amount and consequent security of the fund."

Professor Kroeh also addressed the meeting, calling attention to the directions in which the Institute might develop if the means to do so were available.

A vote of thanks was tendered to Mr. Parsons for the able manner in which he had performed his duties as President of the association.

The meeting then adjourned.

There were present at the meeting:

President Morton.
Professor Kroeh.
G. C. Henning, '76.
A. Riesenberger, '76.
Wm. E. Geyer, '77.
Durand Woodman, '80
Alex. C. Humphreys, '81.
Thos. B. Stillman, '83.
Wm. H. Bristol, '84.
E. H. Foster, '84.
D. S. Jacobus, '84.
H. de B. Parsons, '84.
Geo. J. Roberts, '84.
Edwin Burhorn, '85.

Chas. E. Machold, '85.
John M. Rusby, '85.
R. M. Anderson, '87.
J. Day Flack, '87.
B. F. Hart, Jr., '87.
Jos. A. McElroy, '87.
Franklin Moeller, '87.
C. H. Page, Jr., '87.
H. A. Bang, '88.
Gordon Campbell, '88.
George Dinkel, Jr., '88.
Paul Doty, '88.
Alten S. Miller, '88.
Wm. B. Yereance, '88.
R. C. Oliphant, '89.
J. S. DeHart, Jr., '90.
L. H. Nettleton, '91.
H. H. Adams, '93.
A. B. Brookfield, '93.
O. G. Dale, '93.
F. D. Furman, '93.
E. D. Lewis, '93.
E. P. Buffett, '94.
C. W. MacCord, Jr., '94.
L. Ruprecht, '94.
A. F. Ganz, '95.
R. Gunagan, '95.
R. E. Hall, '95.
B. H. Jackson, '95.
Howard Maxfield, '95.
F. N. Taff, '95.
Wallace Willett, '96.

OBITUARY.

The death of Martin G. Lilly occurred March 2, 1895, at his residence, 725 Philadelphia street, York, Pa.

The INDICATOR takes the first opportunity since this information was received to record the sad event and to recall to the memory of his many friends among the alumni of Stevens his kind and sympathetic nature and to testify to the high esteem in which he was held.

The immediate cause of Mr. Lilly's death was apoplexy superinduced by some brain affection. Death was sudden, occurring after an illness of only 24 hours.

The deceased was 30 years of age.

His early education was obtained at the York County Academy. In September, 1881, he entered the Sophomore Class in Pennsylvania College and attended there until the end of the second term of the Junior year. He then entered the Stevens Institute, joining the class of '86 in the third term of the Freshman year and graduating with the class in June, 1886.

His record in scholarship was uniformly high and his earnest and persistent application to his studies indicated that he had chosen a profession for which he possessed special ability. The industry that characterized his work as a student was subsequently manifested in his practical work as an engineer.

Immediately after graduating Mr. Lilly accepted a position in the draughting department of the Pennsylvania Steel Works, at Steelton, Pa. In 1892 he was appointed to the position of Assistant Engineer in the construction of the great Belt Line bridge across the Mississippi at Alton, in which capacity he was engaged until the completion of the bridge in 1894.

He was married in June of this year to Miss Anna M. Baer, only daughter of Mr. J. H. Baer, of York, Pa., who survives him.

Beginning with the fall of 1894 and until the time of his death Mr. Lilly was a member of the firm of W. H. von Mengemighausen Co., Mechanical and Constructing Engineers, in York, Pa.

INSTITUTE NOTES.

In answer to a communication in which Commodore Melville was notified of the action of the Board of Trustees in conferring the degree of Doctor of Engineering upon him he replied:

WASHINGTON, D. C., June 20, 1896.

DEAR PRESIDENT MORTON: The unexpected honor conferred upon me by the Trustees of the Stevens Institute of Technology is gratefully appreciated, and I desire to express both to you and the Board my sincere thanks for this mark of esteem.

By reason of the distinguished patriotism of its founder the work of the institution at Hoboken has always been watched with great interest by those technical experts of the executive departments of the Government who have been intrusted with the defense of the country, and therefore it gave me exceeding pleasure to receive your commendation.

It is a matter of peculiar pride that with each succeeding year the Bureau of Steam Engineering is coming in closer touch with the scientific institutions, and it is my sincere wish that this policy may be continued, for I am sure that it will result in mutual benefit to engineering science and to the naval service. It will afford me peculiar satisfaction to advance at all times the interests of the institution which has so highly honored me. I am,

Very sincerely,

GEO. W. MELVILLE.

PRESIDENT HENRY MORTON, Ph. D.,
Stevens Institute of Technology,
Hoboken, N. J.

PRESIDENT MORTON and family left town on June 22, to spend the summer at Pine Hill, Ulster County, N. Y.

ON TUESDAY EVENING, May 5, Dr. S. Hasbrouck delivered a very interesting lecture on Egypt before a small but select audience, at Quartette Club Hall, Hoboken. The proceeds he donated to the Alumni Building Fund. The lecture was attractively illustrated by stereopticon views, which were remarkably beautiful.

ON FRIDAY, MAY 22, about half the Junior Class visited the large steel and iron works of the Bethlehem Iron Co., at South Bethlehem, Pa. They were accompanied by Professor Denton, and had every advantage afforded them by Mr. M. White, '79, who showed the class through the works. The following day a large party of Sophomores arrived, and in company with the Juniors visited the zinc works located at Bethlehem, where they were treated with the greatest courtesy.

ABOUT 140 APPLICANTS presented themselves to take the June examinations for admission to the Institute.

Of this number 57 took only the preliminary subjects, and expect to enter a year from next September.

Seventy-five per cent. of this year's applicants attended the Stevens School, having taken either a part or the whole of the course in this school.

THE JEFFREY MANUFACTURING CO., of Columbus, Ohio, presented to the Institute two sets of framed photographs of some of their mining appliances.

THE INSTITUTE LIBRARY has recently been presented by the Department of the Interior, Washington, D. C., with a complete set of the U. S. Geological Survey Reports. Complete sets of these reports are now exceedingly difficult to obtain, as the Government has no more for distribution.

The Library has also been presented with a bound volume containing the catalogues of Fraser & Chalmers, Chicago, Ill., which give a complete set of illustrations of the machinery manufactured by this firm.

THROUGH THE EFFORTS of M. N. Moore, '98, the Institute has been presented with a complete model plant of the Westinghouse Company's Air-Brake System.

THE UNDERGRADUATE REPRESENTATIVES, who, in conjuction with President Morton and a committee acting for the Executive Committee of the Alumni Association, prepared a program of events to comprise the twenty-fifth anniversary celebration of the Institute, were R. V. Rose and W. Kidde, '96, W. H. Miller, '98, and Geo. H. Beck, '99. This program was adopted at the meeting of the Alumni Association, and is given in the account of its proceedings.

PROFESSOR KROEH, WHO IS CHANCELLOR of the Summer Schools at Point O'Woods, Long Island, N. Y., will again have charge of the School of Modern Languages for the season of 1896, from July 4 to September 7.

The School of Mathematics will be under the direction of Professor Webb, who will be assisted by Professor Ganz.

"RESEARCHES ON THE RÖNTGEN RAYS" is the title of an article contributed by Professor Mayer to the *American Journal of Science*, June, 1896. The contents of the article give an idea of its scope. They are as follows:

1. The Röntgen rays cannot be polarized by passing through herapathite. 2. The density of herapathite. 3. The formulæ of transmission of the Röntgen rays through crown glass, aluminum, platinum, green tourmaline, and herapathite. 4. The actinic action of the Röntgen rays varies inversely as the square of the distance of the sensitive plate from the source of the rays.

PROFESSOR JACOBUS HAS BEEN INVITED TO ATTEND the 66th meeting of the British Association for the Advancement of Science to be held in Liverpool,

September 16 to 23, 1896, and to be the guest of the Executive Committee during his stay in that city.

The Committee in extending the invitation to Professor Jacobus expressed a strong desire of making the presence of foreign visitors a prominent feature of this meeting. The Association is specially anxious to secure the presence of representative scientific men from this country whose names are associated with investigation and research in the various branches of science. Opportunity will be given to visitors of seeing points of interest in the neighborhood of Liverpool and of becoming acquainted with some of the most important branches of industry in that country.

THE SUBJOINED LETTER appeared in the *American Gas Light Journal* of March 30, 1896:

STEVENS INSTITUTE OF TECHNOLOGY,
HOBOKEN, N. J., March 24, 1896.

To the Editor *American Gas Light Journal:* I notice in the editorial columns of your *Journal* for March 23, under the heading "Measurement of High Temperatures," an abstract from a paper recently published in a German journal, in which it is stated that there are only three methods by which high temperatures may be accurately measured. As I happen to know about another which has received, and is receiving, very extensive and successful practical application, and which would, I believe, be of great value in water gas plants, I think I shall do a good turn to your readers by drawing their attention to it. I allude to the method which depends upon the different amounts of gas which will flow at different temperatures through the same small aperture. In the pneumatic pyrometer of Uehling & Steinbardt, which is now in constant use in a number of blast furnaces in this country, this principle is so applied as to give a continuous record for 24 hours at a time, so that a furnace manager can see for himself exactly what has been going on in his furnace continuously, for any length of time, by simply examining the autographic records. I speak on the basis of personal knowledge as to the use of these pyrometers for about two years in the furnaces of a large iron company in which I am interested as a stockholder and director.—HENRY MORTON.

AT A MEETING OF THE ENGINEERS' CLUB of Philadelphia held April 18, 1896, in discussing the resolution: "That the Engineers' Club of Philadelphia respectfully urges its representatives at Washington to advocate the adoption of the metric system as the only legal standard in the United States, and to promote such international co-operation as will provide unity of practice amongst commercial nations," Dr. Coleman Sellers said: I encouraged the adoption of the metric system into a department of one large shop long before it was legal in America, and strongly advocated its being made legal. I think it is proper that every citizen should have the right to use the metric system if he finds it to his advantage to do so, but I know, from more than 40 years' experience, that it is not well adapted to mechanical engineering, nor would it be possible to carry on

such a change without an expense entirely disproportionate to any hypothetical advantages it might give.

AT A MEETING of the New York Academy of Sciences held May 4, 1896, Professor Mayer presented a paper on "A Heliostat with Small Mirrors, Giving a Beam of Intense Light and Forming an Image at Its Focus."

PROFESSOR LEEDS read a paper on May 8, 1896, before the New York Section of the American Chemical Society on "Bacteria in Milk Sugar."

A CHAPTER OF THE HONORARY association of Tau Beta Pi, established at Lehigh University in 1855, has recently been formed at the Institute.

The object of this association is set forth in the preamble to its constitution and is as follows:

"To mark in a fitting manner those who have conferred honor upon their Alma Mater by a high grade of scholarship as undergraduates or by their subsequent attainments as alumni, and to foster a liberal culture in the technical and scientific schools of the United States."

Stevens Life in a recent issue contains the following relative to the selection of members in this association:

"High rank is not the sole requirement in a candidate for membership, but he must be a man who can be lived with, as success in after life will depend as much on the adaptability of a man as on what he knows. While, therefore, high rank will put a name on the list of candidates, it will not force its owner into a society against its best interests; and an elective requirement was introduced, so that all who have shown a lack of congeniality, or who have been visited by public reprimand or other penalties for dishonesty in university work, and have failed to exonerate themselves, are passed by at the election. A minimum grade of 75 per cent. is required, and at the beginning of the third term, the highest eight of the Junior Class are admitted, and in the following October the next highest eight, making in all the highest quarter of the class. The list of candidates is furnished to the Association by a member of the Faculty who makes up the marks from the official records. This list is therefore an impartial one, and the rank is carefully computed."

The charter members of the chapter at Stevens are: D. S. Bushnell, B. C. Clark, C. F. Collyer, W. E. Denton, Celestino Garcia, S. Hollingsworth, J. P. Kennedy, W. H. MacGregor, W. C. Maul, C. B. Peck, John Schimmel, Jr., M. V. G. Smith, E. M. Toby, all of the class of '96.

THE ENGINEER DIVISION of the New Jersey Naval Reserve has met with the most hearty support from the students. Out of a maximum roll of 80 there are 65 on the roster, of whom over 40 are Institute men, while the rest are engaged in some technical occupation.

This is the first organization of its kind in the country. Massachusetts has an engineer staff, and some other States have officers in this branch of the service, but none has a regularly organized division for this work.

The officers of the Division, Lieutenants Hart and Fraser, are both graduates of the Institute. There was some delay in mustering in on account of the low condition of the appropriation, but the last Legislature dealt very liberally with the Reserve. The greater part of the dull season which remained after mustering in was spent in breaking the men into ship and company discipline, in order to make a good appearance on the Decoration Day parade.

The U. S. S. "Portsmouth," which is used as a training ship, has been completely overhauled and is nearly ready to go into commission. She is as staunch as the day she shipped on her first cruise to maintain the slave blockade on the African coast.

She was originally fitted with an old locomotive boiler, which was used in furnishing fresh water and for heating purposes. This boiler has been taken out and a compact marine boiler, a Rogers engine, and a 150-light machine have been installed by the Division. The ship has already been completely wired.

The Division entered a crew in the Passaic River Regatta at Newark on Decoration Day, composed exclusively of 'Varsity men. In spite of their light weight, only averaging 130 pounds, and the short time they were in training, they led at the finish by a quarter of a length against a more experienced crew which averaged between 175 and 180 pounds.

The crew also entered the Valencia Regatta on June 27, for which the *Evening News* offered a silk cutter's ensign as a trophy; this they secured, winning by half a boat's length.

A band concert will be given on board on the evening of July 15, to which a number of distinguished guests have been invited.

The annual cruise takes place the last week in July. It will be up Long Island Sound, stopping at all the principal harbors on the way.

THE EXECUTIVE COMMITTEE of the Alumni Association held its regular meeting on April 7, 1896, at the "Arena," New York City.

There were present H. de B. Parsons, R. C. Oliphant, H. Van Atta, K. Torrance, F. D. Furman, A. Riesenberger, and J. Day Flack.

A committee consisting of Messrs. Riesenberger, Bristol, and Furman was appointed, with full power to act, to consider the proposition made by Dr. Hasbrouck to lecture for the benefit of the Building Fund.

An application for assistance to meet his tuition bills was made by a member of the Junior Class and was granted.

Committee on Safe reported having secured through the kindness of Professor Graydon, a loan of a safe, for an indefinite time, for the use of the Association.

A committee consisting of Messrs. H. Van Atta, K. Torrance, and A. Riesenberger was upon motion appointed by the chair to formulate a plan for the observance of the twenty-fifth anniversary of the Institute, and to co-operate to this end with President Morton and a committee of undergraduates.

The Committee of Arrangements for the midwinter meeting reported that the price per plate for the collation was 75 cents, and that 150 plates had been contracted for. The Committee was discharged with thanks.

The action of the Executive Committee with reference to the publication of the names of delinquents, taken at a previous meeting, was upon motion modified to the effect that a list of these delinquents be inserted in the July INDICATOR.

The committee appointed in the case of a beneficiary reported that they could not get party to pay his indebtedness or to admit the obligation.

It was, upon motion, agreed to recommend that the Association take final action in this matter at the June meeting.

The following nominations were received and made for the coming election:

President: J. R. Lieb, Jr., '80; H. R. Rea, '84.

First Vice-President: R. C. Oliphant, '89; Anson Burchard, '85.

Second Vice-President: R. M. Dixon, '81; W. A. Ackerman, '90.

Corresponding Secretary: F. D. Furman, '93; Edw. Burhorn, '85.

Recording Secretary: J. D. Flack, '87; D. H. Gildersleeve, '89.

Treasurer: W. H. Bristol; Robt. M. Anderson, '87.

Directors: A. S. Miller, '88; E. P. Mowton, '86; W. W. Randolph, '86; E. A. Uehling, '77; P. E. Raqué, '76.

Alumni Trustee: H. de B. Parsons, '84; H. Van Atta, '81; J. R. Lieb, Jr., '80.

AT the May meeting the Anniversary Committee, presented a preliminary report, which was discussed, but no action was taken.

The June meeting was held at the Engineers' Club, and the Executive Committee were guests of President Parsons.

The members in attendance were: H. de B. Parsons, A. de Bonneville, Kenneth Torrance, W. H. Bristol, A. Riesenberger, Robert Oliphant, J. W. Lieb, Jr., F. D. Furman, J. D. Flack.

Editors of the INDICATOR submitted a report of assets and liabilities, which was upon motion accepted and ordered filed.

It was upon motion decided that the INDICATOR pay interest at 4 per cent. from January, 1896, on loan of $600 from the Beneficiary Fund.

The following resignations were accepted: David Corbin, '94; K. L. Martin, '92; Geo. W. Merritt, '91; Philip Wallis, '79; Jas. H. Scott, '89.

The Treasurer was instructed to reinstate those members who have paid up back dues and to notify these members of their reinstatement.

The Anniversary Committee made a report, which was accepted and ordered read at the annual meeting. A letter from A. de Bonneville, objecting to the action with regard to delinquents, was read and ordered filed. The votes cast for officers for the ensuing year were then canvassed, after which the meeting adjourned.

DURING the progress of a research on the tension of the surfaces of liquids, Professor Mayer has discovered a remarkable property of aluminum. This property is best described in the account of the following experiment:

A ring 5.2 centimeters in diameter is made of aluminum wire $\frac{1}{2}$ millimeter, or $\frac{1}{100}$ inch, thick. This ring will float on water. Gradually loading the ring it sinks deeper and deeper below the general level of the water, and when 2 grams have been added to the weight of the ring it sinks $\frac{1}{8}$ inch. A slight additional weight causes the ring to break through the elastic skin of the water.

From the data given by this experiment Professor Mayer computed that a ring formed of aluminum rod $\frac{1}{4}$ inch thick should float on water. The ring formed of this wire, which actually floated on water, was about $2\frac{1}{2}$ inches in diameter and weighed $5\frac{1}{2}$ grams. The manner of making these experiments and their important bearings on methods of determining the superficial tension of water, etc., will be discussed in the paper to be published by Professor Mayer.

INSTITUTE PERSONALS.

'75.

A. SORGE, JR., was elected President of the Western Foundrymen's Association, but believing that he could serve the Association better out of the presidential chair than in it, declined the honor. He was subsequently elected Secretary of the Association.

'76.

WILLIAM KENT presented a paper at the St. Louis meeting of the American Society of Mechanical Engineers, May 20, 1896, "On the Efficiency of a Steam Boiler; What is It?"

'77.

E. P. ROBERTS has been appointed Consulting Engineer for the Columbus, O., State Hospital. He was engaged in a similar capacity for the Massillon, O., Insane Asylum.

'78.

E. P. THOMPSON, with the assistance of Prof. W. A. Anthony and Messrs. L. M. Pinolet and Ludwig Gutmann, is writing a book on "Röntgen Rays." D. Van Nostrand Company will be the publishers.

A. A. DE BONNEVILLE has resigned his position with the George F. Blake Manufacturing Company and now represents M. T. Davidson, manufacturer of steam pumps, 133 Liberty Street, New York.

H. T. BRÜCK was married to Miss Minnie Orme Kenah at Baltimore, Md., on April 28, 1896.

'79.

PHILIP WALLIS is a member of the committee appointed by the Master Mechanics' Association, "To consider different types of balanced valves, their economy and efficiency over plain unbalanced slide valves, and what difference in economy and efficiency (if any) would result if above types of valves were provided with the Allen port." The committee conducted a series of tests at Purdue University, Lafayette, Ind.

'80.

JOHN W. LIEB, JR., has been selected as one of the Council Nominees for manager of the American Institute of Electrical Engineers. An article entitled "An Historic Electric Station," by Mr. Lieb, appeared in the May issue of *Cassier's Magazine*. The article, which is an extract of a paper

read before the New York Electrical Society, contains a large cut of the Edison Jumbo Dynamo of 1881.

The same magazine for June contains an article by Mr. Lieb on "Electric Current Supply from Central Stations."

'81.

ALEX. C. HUMPHREYS presented a paper, entitled "Self-Education in Gas Engineering," to the annual meeting of the Western Gas Association, held at Lookout Mountain, Tenn., May 20–22, 1896. The paper is published in the *American Gas Light Journal* of June 1.

WM. T MAGRUDER is Chief of Machinery of the Tennessee Centennial Exposition, to be held a year hence at Nashville, Tenn. Mr. Magruder is preparing a paper on "Credit for Shop Experience in Entrance Examinations," which will be presented at the meeting of the Society for the Promotion of Engineering Education, to be held at Buffalo, N. Y., next month.

'83.

L. S. RANDOLPH has been elected a director of the Association of Engineers of Virginia.

'84.

H. DE B. PARSONS delivered a lecture on "Heating and Ventilation" before the students of the Rensselaer Polytechnic Institute April 2, 1896. The lecture was published, in part, in *The Engineering Record* May 2, 1896.

Mr. Parsons is one of the regularly appointed lecturers at the above institution, and has been lecturing there, upon engineering subjects, for a number of years.

An article on "Fire Boats," with illustrations showing the floating fire equipment of different cities, was contributed by Mr. Parsons to the May number of *Cassier's Magazine*.

LAFAYETTE D. CARROLL is in the employ of Humphreys & Glasgow and is located at their London office, No. 9 Victoria Street.

J. A. BENSEL, of the firm of Steers & Bensel, contracting engineers, is established at No. 5 Bowling Green, New York City.

'86.

C. RUSSELL COLLINS, who was Manager of the Manhattan Incandescent Light Company of New York, resigned that position and is now established as Gas Engineer in the New Jersey Central Railroad Building, New York City.

In regard to Mr. Collins' connection with the above company, *Progressive Age*, May 1, 1896, says: "Mr. Collins assumed charge of the Welsbach business in this city at a time when the affairs connected with the light in this vicinity were anything but satisfactory to anyone, and in the year since he has had the direction of the enterprise order has

been brought out of chaos, and nowhere is a larger business being done by the Welsbach Company than in New York."

THE MAY NUMBER of *Cassier's Magazine* contains an article by Otto Pfordte on "The Washing of Gold Placers in South America." The article describes the character, locations, and methods of working these gold deposits.

'87.

H. A. WAGNER presented a paper on "Flywheels" at a meeting of the Engineers' Club of St. Louis, Mo., June 3, 1896

Mr. Wagner was elected a member of the Executive Committee of the National Electric Light Association. He attended the convention of this Association, held at the Grand Palace, New York City, May 5–7, 1896.

'88.

B. P. HALL is Superintendent of the New York Steam Fitting Company, 211 Centre Street, New York City.

'89.

ROBERT KEATING SMITH was married to Miss Bertha H. Wiles, on Wednesday, June 17, at St. Peter's Church, Albany, N. Y.

'90.

W. N. CARLTON has been elected an associate member of the American Society of Mechanical Engineers.

'91.

S. L. G. KNOX has accepted the position of Chief Draughtsman of the Crocker-Wheeler Electric Co., Ampère, N. J.

W. H. SMITH was married to Miss Laura B. Manning on Wednesday, June 17, 1896, at Elizabeth, N. J.

'92.

H. W. JACKSON is Superintendent of the factory of the Essex Lamp Co., Newark, N. J., and is also a member of the firm.

'93.

CHARLES T. BAYLES has been elected a junior member of the Amer. Soc. of Mech. Engineers. Mr. Bayles now holds the position of Assistant Mechanical Editor of the *Railway Gazette*, 1750 Monadnock Building, Chicago, Ill.

'94.

A. M. LOZIER has been elected to associate membership in the American Institute of Electrical Engineers.

J. W. GILMORE was married to Miss Helene Louise Hitchcock on May 25, 1896, at Christ Church, Grand Boulevard and Seventy-first Street, New York City.

M. W. KELLOGG is with W. T. Hiscox & Co., jobbers of mill supplies, 26 Fifth Street, New York City.

E. J. BURKE is employed in the Fifty-second Street shops of the Brooklyn Heights Railway, Brooklyn, N. Y.

F. H. COYNE is Assistant Manager of a gold mine at Angel's Camp, Calaveras County, Cal.

'95.

C. J. SLIPPER is with the Manhattan Incandescent Light Company, 931 Broadway, New York City.

WILLARD BROWN has left the employ of the Pencoyd Iron Works and is now with the King Bridge Company, Cleveland, O., assisting the mechanical engineer in the construction of conveying and hoisting machinery for coal and ore.

'96.

ARTHUR J. WOOD is doing editorial work upon the staff of *The Railroad Gazette*, 32 Park Place, New York City.

W. R. WILSON is about to enter the employ of the Pencoyd Iron Works, Philadelphia, Pa.

ATHLETICS.

LACROSSE.

With the close of the lacrosse season of this year comes more or less disappointment over the inability of the team to win championship honors in the Intercollegiate League, but nevertheless a feeling of appreciation of the splendid work which it has done.

It is true that the game with Lehigh contained an unpleasantness which operated most disastrously in the final outcome of the series, and it was certainly an unfortunate occurrence; but it is necessary to yield to the inevitable and accept defeat gracefully.

For the second consecutive time Lehigh is to be congratulated, while at the same time Stevens looks forward to what it hopes will be a more successful season.

The following games were played:

April	18,	at Hoboken;	Stevens 0,	Crescent A. C. 4.
"	22,	" "	" 5,	C. C. N. Y. 0.
"	25,	" "	" 9,	" 0.
"	29,	" "	" 10,	" 0.
May	2,	" Bay Ridge;	" 3,	Crescent A. C. 6.
"	6,	" Hoboken;	" 2,	C. C. N. Y. 0.
"	7,	" Bay Ridge;	" 3.	Crescent A. C. 3.
"	9,	" Hoboken;	" 8,	Johns Hopkins 1.
"	15,	" "	" 5,	Harvard 2.
"	23,	" Bethlehem, Pa.;	" 3,	Lehigh 4.
"	30,	" Bergen Point;	" 1,	Crescent A. C. 4.

STEVENS *vs.* CRESCENTS.—Although Stevens was unable to win from Crescent, her play in each succeeding game showed marked improvement. The first game contained much fumbling, poor passing and shooting, but on the whole was a very creditable performance, considering the fact that but a week's practice had been indulged in, and the Junior ball occurred the night before.

The second game was characterized by good team work, skillful uncovering and tipping in the attack.

The third was the best of the series, and Crescent came very near meeting her Waterloo. It was only during the last few minutes of play that she managed to shoot two goals, thereby tieing the score.

The last was the most uninteresting game of the season, and very little interest in it was shown.

STEVENS *vs.* C. C. N. Y.—A serious handicap to the C. C. N. Y. team is their inability to secure grounds upon which to practice. Although no match for Stevens, yet they afford excellent practice, and present a fine example of pluck.

STEVENS *vs.* JOHNS HOPKINS.—Too much praise cannot be given our team for their fine exhibition of lacrosse in the first game of the championship series. There was almost an entire absence of body-checking and shinney work, and an abundance of fine plays, in which was noticed some pretty tipping, passing, dodging, long throwing, and splendid team work, the whole affording a very interesting, though one-sided contest.

The teams lined up as follows:

Stevens.	*Positions.*	*J. H. U.*
Sofio	Goal	Mitchell.
Buckley	Point	Dawson.
Willett	Cover point	Stevens.
Brune	1st defense	Strobel.
Grelle	2d defense	Lupton.
Lent	3d defense	Belknap.
Weichert	Center	Lacy.
Hardie	3d attack	Warfield.
Bruckner	2d attack	Reese.
Jennings (Capt.)	1st attack	Shaw.
Scott	Outside home	Hill (Capt.)
Macbeth	Inside home	Straus.

Referee—Mr. Richards.

Umpires—Messrs. Cameron and Furman.

Goals—Hill, Weichert, Bruckner, Jennings 2, and Scott 4.

Bruckner got the ball the instant after it was faced, and passed to Jennings, who shot unsuccessfully. During the next few minutes our attack had a dozen shots, some of which would have resulted in goals, but for fine stops by Mitchell. The ball then went down to our defense, but Weichert returned it to Bruckner, who dodged his man, and shot our first goal.

In resuming play, J. H. U. shot twice, but Sofio stopped both. After several attempts at goal by our attack, Scott was hurt; and although he finished out the game, his injury proved quite serious, and necessitated his retirement for the remainder of the season. A moment later, on a pass from Weichert, Scott scored our second goal.

After several shots from both attacks and a fine return by Willett, Lent shinnied to Scott, who shot Stevens' third goal. After some pretty work by Brune, and good catches by Willett and Buckley, time was called.

The second half was begun with a pass by Jennings to Scott, who shot our fourth goal. Then followed some hard drives at goal which were beautifully stopped by Mitchell. Dawson got the ball by good work and sent it to his attack, where Shaw narrowly missed a goal, knocking down one of the posts.

A few minutes after, Macbeth was taken with a cramp. When play began again, Hill secured the ball, and shot his team's first and only goal.

When the whistle blew again, Willett made one of his long underhand throws to the left of Hopkins' goal. Hardie sent the ball into our attack, and Scott shinnied it between the posts.

In less than a minute after, Weichert made a pretty catch and dodge, and a fine goal.

At this point of the game, Lacy was hurt, but resumed his play. Grelle got in some good work, Bruckner a shot, while Sofio stopped a hard drive. Jennings then picked the ball from a scrimmage, and shot a beautiful goal at Mitchell's feet. A few minutes before time was called, Jennings duplicated his last goal, which made the final score, Stevens 8, Hopkins 1.

All the Stevens men played their positions to the entire satisfaction of their able coach, Mr. Garvin of Crescent; while for J. H. U. Mitchell did by far the best work.

STEVENS *vs.* HARVARD.—Harvard outran Stevens, and her stick work and team play were superior, but for all that she was unable to secure the larger number of goals.

The Cambridge men were in perfect condition, due to their careful training, and showed very little sign of exhaustion after the game. The first half was very spirited and interesting, while in the second the Stevens' attack went to pieces, and had it not been for the fine work of the defense, Harvard certainly would have scored. Time and again the concerted play of Beecher and Leighton would bring the ball dangerously near Stevens' goal, only to be returned by the long throws of Buckley and Willett.

The teams lined up as follows:

Stevens.	*Positions.*	*Harvard.*
Sofio	Goal	Scott (Capt.)
Buckley	Point	Sand.
Willett	Cover point	Woods.
Brune	1st defense	Starr.
Grelle	2d defense	Able.
Lent	3d defense	Dearborn.
Weichert	Center	Horne.
Hardie	3d attack	Beecher.
Bruckner	2d attack	Leighton.
Kelly	1st attack	Curtis.
Jennings	Outside home	Burley.
Macbeth	Inside home	Ring.

Referee—Mr. Hunter, Stevens, '97.

Umpires—Messrs. Taylor, Harvard, '98, and Hunt, Stevens, '96.

Goals—Jennings 2, Kelly, Beecher, and 3 shinnied.

STEVENS *vs.* LEHIGH —On Saturday, May 23, our team journeyed to Bethlehem, Pa., only to be defeated in the final game for the much coveted championship banner.

Stevens played a plucky game, but a game almost devoid of head work; indeed, but for the star playing of Weichert, and the defense work of Sofio, Buckley and Willett, the game would have been thoroughly one-sided.

The team work of Lehigh was of the A No. 1 order, but she was extremely weak at shooting, many an easy shot going ten or fifteen feet wide of the posts.

The main features of the game were the playing of Weichert and the exceptional catching and dodging of Barthes.

The teams lined up as follows:

Stevens.	*Positions.*	*Lehigh.*
Sofio	Goal	Pennington.
Buckley	Point	Williams.
Willett	Cover point	Miller.
Brune	1st defense	Enscor.
Grelle	2nd defense	Boyt.
Lent	3rd defense	McDonald.
Weichert	Center	Schriver.
Hardin	3rd attack	Roundy.
Bruckner	2nd attack	Merriman.
Kelly	1st attack	Barthes (Capt.)
Jennings	Outside home	Baldwin.
Macbeth	Inside home	Boyer.

Referee—Mr. Coleman.

Umpires—Messrs. Wilson, Lehigh, '96, and Mathey, Stevens, '97.

Goals—Jennings, Weichert 2, Schriver, Roundy and Baldwin 2.

Almost immediately after the ball was faced it went down to our defense, was returned by Weichert, caught by Lehigh's defense, who threw to their attack, where Baldwin, by fine dodging, succeeded in passing all but Sofio, and shot a close, easy goal.

During the next few minutes Bruckner and Macbeth each made unsuccessful attempts at goal, after which the ball went to Lehigh's attack, where it was passed to Baldwin, who was uncovered. He ran in and shot, the ball striking Sofio on the shoulder,who was several feet in front of the goal, and bouncing over the posts. It was a close decision, and although it aroused considerable dissatisfaction, was nevertheless proclaimed a goal.

After a fine stop and shot by Brune, Jennings passed the ball to Weichert, who threw a very pretty goal.

It was not long after this that Lehigh's captain was hurt, but he did not retire from the game. Our next goal was the result of good work by Brune and Grelle, and a pass by Weichert to Jennings, who shot squarely between the posts. Thus ended the first half, with the score standing 2–2.

SECOND HALF.

Lehigh's attack put plenty of vim into their work, and after five wild shots and one which was stopped by Sofio, Roundy shot low, the ball striking the ground twenty feet in front of the goal and bouncing high over Sofio's head. It was counted Lehigh's goal, however, and put her in the lead.

After three unsuccessful attempts at goal, one of Lehigh's attack managed to pass all of our defense men save Sofio, and it looked as though

he had things all his own way, when Buckley, who was following him closely, with one great effort managed to check his shot. A few minutes later Schriver caught the ball, and after the failure of three of our men to check him, shot a pretty goal.

It was now Stevens' turn to take a brace, and during the remainder of the game she played desperately. Bruckner and Jennings each shot, but fine stops prevented their scoring. It was at this exciting stage that the best piece of individual work in the game took place. Weichert picked up the ball in the center of the field, dodged neatly two of Lehigh's defense men, and, while running at full speed, shot as pretty a goal as ever was made.

Although the ball stayed in the neighborhood of Lehigh's goal during the remainder of the game, no one came to the rescue with the tieing point, and the contest ended with Lehigh as the champion of '96.

SOPHOMORE *vs.* FRESHMEN.—The annual game of lacrosse between the Sophomore and Freshmen classes resulted in a victory for '98 by a score of 2–0.

The Freshmen turned the tables in the baseball game, winning by a score of 26–21.

THE TENNIS CLUB held their annual meeting on Wednesday, April 15, and elected the following officers: President, P. Litchfield; Vice-President, Milton Ruggles.

The interclass tournament was won by Graham King, '99.

BERKELEY OVAL WAS the scene of a baseball contest between '99 and Berkeley School, on May 7. The game was one-sided, Berkeley having the best of it from the start. Score, 9 to 32.

The following are the scores of other games played by the Freshmen Baseball Team:

May 9, Stevens, '99 *vs.* Columbia, '98; score, 9 to 8.

May 13, Stevens, '99 *vs.* Adelphi Academy; score, 16 to 10.

May 20, Stevens, '99 *vs.* Columbia, '99; score, 13 to 7.

The team was made up as follows: H. Sanson, pitcher; H. Berg, catcher; A. T. Hagstoz, 1st base; R. C. Stanley, 2d base; H. Webster, 3d base; J. R. Westerfield, shortstop; F. Sanson, left field; W. D. Church and Geo. H. Stover, center field; M. Kelly, right field.

ACCESSIONS TO THE INSTITUTE LIBRARY, JANUARY, 1896, TO JULY, 1896.

From President Morton.

Transactions of the American Society of Mechanical Engineers. 1895.
The Metallurgy of Iron. By H. Bauermann. 1868.

From Professor Denton.

Refrigerating Machinery. By A. Ritchie Leask. 1895.

From Longmans, Green & Co.

History of Architecture. By A. D. F. Hamlin. 1895.

By Purchase.

Fortschritte der Electrotechnik. By Dr. Karl Strecker. 1895.
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BLAST-FURNACE SLAG AS AN AGENT IN THE PROCESS OF SMELTING.

BY EDWARD A. UEHLING, M. '77.

In the process of smelting ores three distinct products result —viz., metal, gas, and slag.

We here propose to discuss only the latter product in its relation to the process of smelting iron ores in the blast furnace, where, as in all metallurgical operations, it plays a very important role.

In all intelligently conducted furnace practice close attention is paid to the chemical composition of the slag. It is always sought to obtain a slag best suited to accompany the quality of iron which it is the endeavor to produce. The impurities of the ore and fuel and the composition of the flux must be known, and from these data the desired composition of the slag must be calculated as nearly as possible beforehand.

In endeavoring to calculate the composition of the slag the furnace manager is generally confronted with such difficulties that it is but rarely possible to obtain just the slag desired.

In many cases there is little or no choice in the raw material to be used. And where there is a choice, the furnace manager is not generally consulted, and hence the relative contents of the slag ingredients are rarely considered. The price per unit of iron, the ratio of iron to phosphorus, and occasionally of iron to manganese, determine the selection. The ratios of silica to alumina, and of silica and alumina to the lime and magnesia contents are very rarely taken into consideration.

The same thing holds good for the fuel and flux, of which there is generally a less variety and hence less opportunity for making a selection.

The best must therefore be made of the material on hand.

To produce the best results the slag must have certain properties, of which the first and most important is fluidity.

The functions of a blast-furnace slag are twofold: Mechanical and chemical. Fluidity is essential to both.

The chemical functions of the slag are performed in assimilating and retaining such elements as would be injurious to or undesirable to have in combination with the metal. The chemical composition of the slag should therefore be so calculated that it requires these elements to satisfy its affinities.

The mechanical functions of the blast-furnace slag are not less important than the chemical and perform their principal duties: First, in washing the dross from the descending ore, which facilitates final reduction; second, in acting as a filter through which the molten metal passes and is purified; third, in forming a blanket over the molten metal in the hearth of the furnace, and thus protecting it from the oxidizing action of the blast.

Blast-furnace slag, to perform its functions properly, must be sufficiently fluid to percolate through the incandescent fuel with the least obstruction to the upward current of the gases, and after reaching the hearth it should form an even bath, and permit the globules of iron to pass through it freely and accumulate underneath. A dead, sluggish slag not only unduly obstructs the ascent of the gases, interferes with the efficient contact between the oxygen of the blast and the fuel, prevents the small globules of iron from passing through it freely, frequently retaining a large per cent. of metal in that form,* but its chemical functions are also practically neutralized.

To insure a good working slag physical activity (i. e., mobility) is as essential as the proper chemical affinity; fluidity is therefore the prime essential in a blast-furnace slag.

* These globules of iron vary in size from a pea to a pin's head, and slag containing them, called "buckshot," not infrequently holds as high as 70 to 80 per cent. of metal.

A sluggish slag may result temporarily from lack of temperature in the hearth, which lack of heat may be due to water entering the furnace from a leaky tuyere or a cooling plate, or it may be due to insufficient blast temperature or to a sudden descent of unprepared material caused by irregular working of the furnace. At present, however, we shall only consider the characteristics of slags, as they necessarily result from the composition of the burden.

Much has been written about the nature and composition of slags, their basicity and fusibility, classification according to the oxygen ratio, etc. Only incidental mention, however, is made of fluidity, or nothing is said at all. Fusibility and fluidity have either been considered as synonomous or the importance of fluidity has been entirely overlooked.

Slag of a low point of fusion is to be avoided rather than to be sought for in modern blast-furnace practice: first, because low fusing temperature does not, as a rule, imply high fluidity, and then because such a slag becomes pasty too high up in the furnace, in which condition it obstructs the free passage of the gases, prevents their contact with the ore, and has a tendency to stick to the walls, thus causing the descending stock in the furnace to hang and slip.

Before the advent of the superheated blast and the large modern furnace the conditions were different. With cold blast and a small furnace refractory slags could not be used, hence in those days fusibility was of greater importance than fluidity. Slag too thick to run from the timp was removed from the furnace through the "open front" by means of iron bars called "wringers" and great swinging shovels.

The chemical requirements of the slag were also less important. Charcoal was the fuel universally used; its impurities are practically nil. The ores were all carefully selected and well roasted before charging into the surface. In the modern furnace much less attention is paid to the preparation of the ores. Carbonates and Black

Band ores are the only ones regularly roasted. The celebrated Cornwall ore, which carries an excess of sulphur, is the only exception in this country. The modern blast-furnace fuel is coke. Charcoal and anthracite are becoming less and less important as a blast-furnace fuel. Coke contains from 0.75 to 2.50 per cent. of sulphur, and this must be taken care of by the slag. To do this effectively not only the chemical affinity, but also the physical condition of the slag must be right. It must do its work quickly and thoroughly. A good slag must not begin to melt until it gets quite low down in the furnace, and when it begins to melt must melt rapidly into a fluid bath.

There are four principal slag-producing elements in blast-furnace practice—viz., silica, alumina, lime, and magnesia. Manganese occurs occasionally, but it is only rarely that other elements are present in quantities sufficiently large to enter into the calculation. A normal blast-furnace slag should not contain iron in quantities large enough to influence its condition at all, and manganese is only an exceptional ingredient in any considerable quantity. Thus far no satisfactory classification of blast-furnace slag has been proposed. Classification, according to the oxygen ratio of the basic to the acid constituents, is very beautiful and comprehensive, and although based on scientific principle, and readily applicable to all slag combinations, and until something better is found, quite indispensable to the theoretical writer of metallurgical literature and to the teachers of metallurgy, it is nevertheless of little or no real value to the practical metallurgist. Although it is true that a few general deductions, in the direction of practical application, may be based on the oxygen ratio, and that in many cases practice has been greatly assisted by such deductions, yet on the whole there has been much disappointment and disgust among the practical men, and the verdict predominates that the theoretical formulas are worse than useless. While we may not approve of this attitude, the disrepute into which theoretical slag calculations

have fallen can be accounted for by the single fact that alumina, although theoretically much the stronger base, must, when occurring in excessive or even in any considerable proportion, be treated as an acid rather than a base, in order to get a physically satisfactory and chemically efficient slag, if the degree of basicity which produces the best results, when the proportion of alumina is small, is to be preserved.

The fact that in the mineral kingdom all bases replace one another according to their oxygen equivalents, has given rise to the opinion that they must also do so in metallurgical slags. Whether they really do so or not we shall not stop to discuss; it is of no practical importance.

In calculating the desirable composition of a blast-furnace slag, it is not sought to imitate the composition of any mineral, or set of minerals; but has the single object, the smooth and regular working of the furnace, and the production of the desired quality of iron. To bring this about the first requisite is, that the slag, which results forms a fluid bath, and the second, that it possesses the proper chemical affinities.

Silica and lime are the fundamental slag formers. Alumina and magnesia are rarely absent, but enter in much more varying proportions. Manganese, though by no means of rare occurrence, is not a regular slag ingredient in any considerable proportion.

Theoretically the value of the four leading bases as fluxes for silica are as follows:

COMPARATIVE THEORETICAL VALUE OF BASES.

Caustic lime CaO	100	Carbonate of lime $CaCo_3$	100
Caustic magnesia MgO	140	Carbonate of magnesia $MgCO_3$	114
Oxide of manganese MnO	79	Oxide of manganese MnO	141
Alumina Al_2O_3	163	Alumina Al_2O_3	278.5

From the comparison we see that according to the oxygen equivalent, alumina is the strongest flux. Yet in a blast-furnace

slag the less of it the better, and if it cannot be avoided, it must be either diluted by increasing the quantity of slag,* as the writer has had occasion to do, or its bad effect must be neutralized by increasing the basicity of the slag, or, if the basicity is to be preserved, by placing it on the acid side of the equation in your slag calculations†—i. e., treating it as an acid.

Professor Ackerman, the eminent Swedish authority, has made a very elaborate and an exceptionally valuable set of experiments, which are calculated to throw considerable light on the subject of the relative efficiency of the principal basic components of blast-furnace slags. The results of these experiments were published in full in *Jerncontorets Annaler I.*, 1886, and, in extract, in *Stahl und Eisen*, No. 5, May, 1886. The figures here used are either taken directly from Professor Ackerman's tables in the order given by him, or selected from them and rearranged to bring out the fact, long known to many of the practical furnace managers, that the quality—i. e., the behavior—of a slag in the blast furnace does not depend, except in a very general way, upon its degree of basicity or ratio of the oxygen equivalents in the acid to that in the basic components. In Table No. 1 are given the analyses of 46 blast-furnace slags, of which the first seven are from furnaces using coke, and the remaining 39 are from charcoal furnaces. The slags are arranged according to their basicity, commencing with an oxygen ratio of 0.70, and gradually increasing to 1.80, as shown in the last column of the table. The tenth column contains the corresponding heat units absorbed in smelting the respective slags, as determined by Professor Ackerman. On Plate I. these results are graphically represented. There is not much comfort in this exposition to the

* The alumina may be diluted by adding a highly silicious ore and its requisite of lime, as was done with very good effect by the writer at the furnaces of the S. I. & S. Co., or by adding pure silica as was done by C. F. Stewart, at the Soho Furnace, Pittsburg, with remarkably good results

† Von B. Platz, *Stahl und Eisen*, No. 1, 1892, on Blast-Furnace Slags.

TABLE No. 1.

Heat Requirements of Blast-Furnace Slags of Gradually Varying Basicity.

SiO_2 %	Al_2O_3 %	CaO %	MgO %	MnO %	FeO %	CaS %	Oxygen, % in Al_2O_3.	Oxygen, % in total RO Bases.	Heat Units Required.	Basicity
31.40	22.32	30.92	10.02	0.96	0.03	3.85	10.40	13.38	411	0.70
30.08	15.13	35.46	12.33	0.59	0.47	5.72	7.05	15.29	458	0.72
27.84	8.96	33.27	3.87	22.02	0.32	4.03	4.17	16.09	412	0.73
34.65	19.80	37.32	2.62	1.20	0.26	4.93	9.22	12.04	309	0.87
34.85	19.32	38.61	2.30	0.31	0.26	3.91	9.00	12.08	308	0.88
35.90	11.69	42.31	5.40	0.84	0.19	3.91	5.45	14.33	388	0.97
36.24	10.10	42.99	4.77	0.66	0.39	2.95	4.71	14.56	395	1.00
36.15	5.93	29.33	6.08	18.95	0.19	2.92	2.76	15.13	399	1.08
41.20	4.48	28.79	22.02	2.88	0.47	....	2.90	17.78	457	1.11
40.60	11.35	25.77	10.60	10.58	0.64	....	5.29	14.11	346	1.12
41.45	3.69	31.60	19.96	2.30	0.40	....	1.72	17.63	439	1.14
41.99	5.21	31.35	18.40	0.73	0.36	0.52	2.43	16.76	415	1.17
42.90	9.97	26.35	12.26	7.82	0.77	....	4.64	14.25	340	1.21
43.85	8.34	35.00	7.81	2.43	0.90	....	3.88	13.87	369	1.32
44.40	8.92	24.35	11.41	8.59	1.08	...	4.15	13.69	342	1.33
47.16	5.83	21.79	22.18	2.14	0.77	...	3.72	15.75	409	1.36
45.15	5.14	36.85	10.26	2.24	0.29	....	2.40	15 99	492	1.37
43.51	3.92	40.52	5.80	4.22	0.78	0.63	1.83	14.97	381	1.38
47.60	3.43	26.10	15.42	0.99	0.84	....	3.93	14.33	362	1.39
46.01	4.34	32.93	11.46	4.72	0.87	....	2.02	15.24	358	1.42
46.72	4.36	19.10	18.37	11.16	0.70	....	2.03	15.47	388	1.42
47.00	2.40	26.75	18.10	4.46	0.45	....	1.12	16.20	399	1.45
48.50	3.40	20.14	23.79	0.85	2.60	....	1.58	16.03	334	1.47
46.32	4.57	34.05	10.25	2.68	0.52	0.76	2.13	14.55	368	1.48
46.90	4.23	34.64	9.83	3.54	0.80	....	1.97	14.82	367	1.49
48.95	7.75	21.55	18.18	0.91	0.77	...	3.61	13.80	384	1.50
48.90	10.00	22.70	15.24	1.09	1.16	....	4.66	12.08	376	1.53
47.56	5.48	32.26	8.65	5.06	0.38	1.08	2.55	13.90	364	1.54
50.10	70.75	23.80	16.24	1.48	0.50	....	3.61	13.76	368	1.54
47.70	5.80	30.71	8.47	5.67	0.54	0.50	2.70	13.57	348	1.56
49.77	2.86	18.40	21.81	5.85	0.81	...	1.33	15.48	449	1.58
48.90	5.50	30.70	10.20	4.00	0.40	. ..	2.56	13.84	343	1.59
49.60	8.67	32.60	7.72	0.49	0.64	....	4.04	12.64	351	1.59
52.32	5.77	15.05	24.39	1.53	0.81	....	2.69	14.57	435	1.62
51.25	17.30	26.25	2.25	1.26	0.64	....	8.06	8.81	368	1.62
49.40	5.46	31.15	9.16	3.37	1.50	...	2.44	13.65	367	1.64
50.20	4.11	22.20	60.61	3.28	2.75	...	1.92	14 33	405	1.65
52.10	5.74	13.40	23.34	2.76	1 16	....	2.68	14.04	428	1.66
53.20	7.15	17.40	20.39	0.49	0.82	....	3.33	13.42	401	1.69
50.20	8.10	32.30	5.34	2.51	0.79	...	3.77	12.09	366	1.69
52.65	8 54	20.65	15.73	0.59	0.64	....	3.98	12.46	377	1.71
51.40	3.86	25.00	16.06	1.76	1.95	....	1.80	14.17	414	1.72
50.20	3.86	27.22	10.88	5.44	1.80	....	1.80	13.76	370	1.72
53.57	6.45	22.12	16.42	0.57	0.68	....	3.01	13.16	410	1.77
52.30	5.00	26.00	14.20	0.50	1.10	....	2.30	13.40	396	1.78
52.45	12.80	19.15	3.47	11.53	0.45	....	5.96	9.56	353	1.80

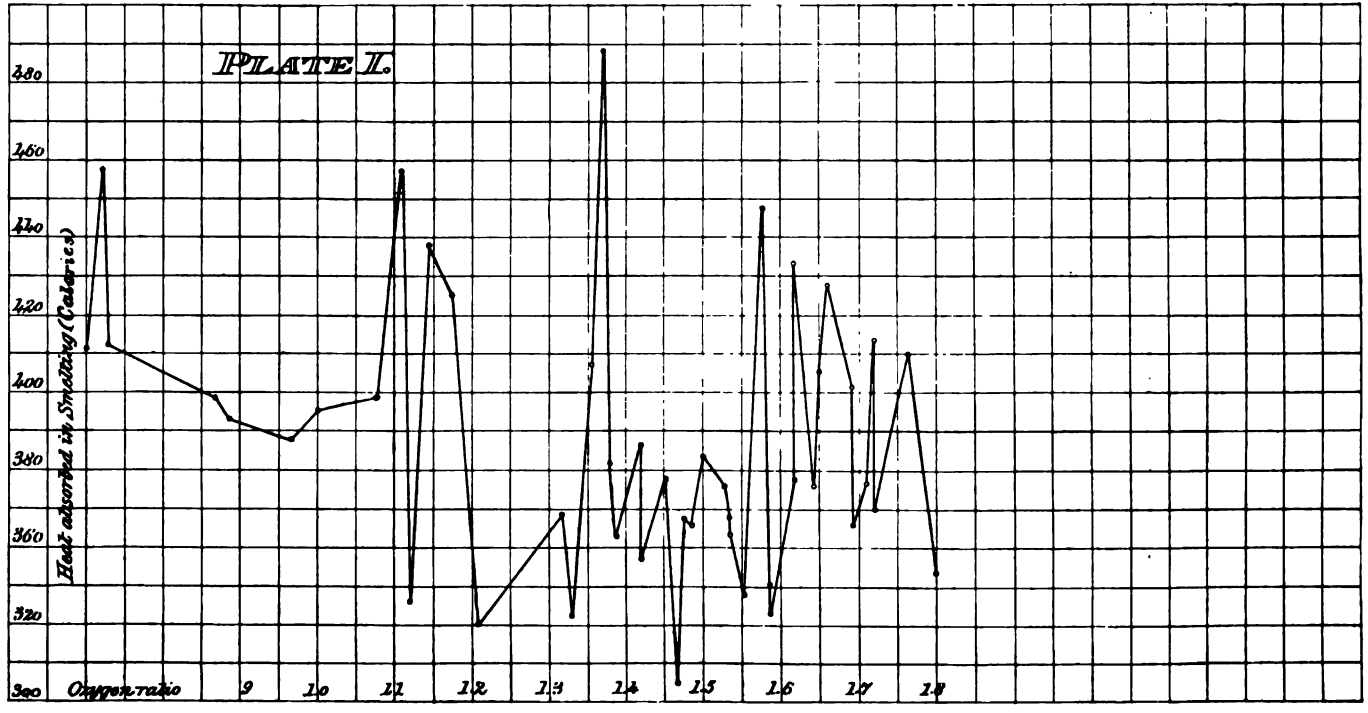
PLATE II.
480
460
440
420
400
380
360
320
300
Heat absorbed in Smelting (Calories)
Oxygen ratio
9
10
11
12
13
14
15
16
17
18

blast-furnace manager who has been endeavoring to regulate the quality of his slag entirely by the oxygen ratio or basicity. The furnace manager who has been fortunate enough to have to deal with raw material in which the relation of the bases remained practically constant, may not have experienced much difficulty in keeping his slag of the right quality, but those who are compelled to use a burden in which these bases do vary considerably, especially if the percentage of alumina varies materially, have found that either their standards of basicity had to be altered or extraordinary means had to be resorted to, to bring about the desired quality in the slag.

Professor Ackerman made a very large number of artificial slags, employing such minerals as would not only enable him to make a composition of any degree of basicity, but also to vary the percentage of any of the components. He determined in each slag so made the heat units consumed in smelting the same. The results obtained are given in a series of tables arranged to bring out the varying qualities of the different combinations. The details of these experiments were not given in the extract in *Stahl und Eisen;* but the reputation of Professor Ackerman is such that we may rest assured that they were carefully executed and conscientiously recorded.

Lime is the principal base in all blast-furnace slags. That this is so is not alone due to its abundance and cheapness, but chiefly to its chemical characteristics. It is the only available base that can practically replace all other bases and produce an efficient blast-furnace slag. It is also the base which takes care of the sulphur, calcium sulphide being the principal, if not the only form in which sulphur is carried by the slag, and lime must therefore predominate if much of this most injurious element is to be removed by the slag.

Alumina has absolutely no affinity for sulphur, and magnesia very little, if any, although it may, and no doubt does, materially assist indirectly in removing sulphur by increasing the fluidity of

the slag. But alumina, if present in any considerable quantity, say above 15 per cent., always acts detrimental to the quality of the iron produced with it, due to its bad effect on the physical quality of the slag, rendering it sluggish and unfit for chemical action. The effect of alumina is in many respects in the same direction as silica, and if the sum of silica and alumina exceeds 50 per cent. of the total slag constituents, the bad effect generally becomes manifest. In order to show the different effects produced in a slag by replacing lime respectively by magnesia alumina and oxide of manganese, we have compiled Table No. 2, in which sections A, B, C, and D are selected from Professor Ackerman's experiments. All the slags in this table have the same degree of basicity—i. e, the same oxygen ratio of acid to bases—viz., 1.50. In the column marked quality, F stands for a short and fluid slag, while S stands for sluggish and stringy. Examining this column we see at once (sections B and D) that the effect of alumina is to produce a sluggish slag. Plate II. represents graphically the effect produced on the heat requirement of slags of the same degree of basicity if lime is replaced by any of the other three principal basic slag components. The first effect of replacing lime by either of the bases is to reduce the heat requirement, which is probably equivalent to reducing the point of fusion. Alumina exerts the greatest effect in this direction, and magnesia the least. It is interesting to note that both magnesia and alumina reverse this tendency and begin to increase the heat requirement before their oxygen reaches one-half that contained in the lime remaining. In the case of alumina this occurs even before the ratio reaches 40. The oxide of manganese forms an exception, and although its influence becomes less and less marked, it does not reverse its tendency. If we assume that increased heat requirement implies increased temperature of fusion, it appears from curves D and B that a slag which contains both lime and magnesia in constant ratio reverses earlier and becomes less fusible than one containing lime alone when gradually

TABLE No. 2.

Heat Requirements of Artificial Slags Selected from Prof. R. Ackerman's Experiments.

	SiO_2 %	Al_2O_3 %	CaO %	MgO %	MnO %	FeO %	Oxygen % in CaO	Oxygen % in MgO	Oxygen Ratio $\frac{MgO}{CaO}$	Heat Units Required.	Quality.	Basicity.
	44.94	0.45	51.80	1.95	0.19	0.67	14.80	0.78	0.05	431	F	1.50
	45.24	0.48	49.84	3.56	0.18	0.70	14.24	1.42	0.10	430	F	1.50
	45.62	0.52	47.33	5.64	0.17	0.72	13.52	2.25	0.17	429	F	1.50
	45.79	0.54	46.17	6.60	0.16	0.74	13.19	2.64	0.20	428	F	1.50
	46.03	0.56	44.55	7.95	0.16	0.75	12.73	3.18	0.25	426	F	1.50
	46.20	0.58	43.43	8.87	0.15	0.77	12.41	3.55	0.29	423	F	1.50
A	46.41	0.60	42.04	10.02	0.15	0.78	12.01	4.00	0.33	419	F	1.50
	46.68	0.62	40.24	11.51	0.14	0.80	11.50	4.60	0.40	413	F	1.50
	46.85	0.64	39.13	12.43	0.14	0.81	11.18	4.96	0.44	411	F	1.50
	47.10	0.70	37.80	13.50	0.10	0.80	10.80	5.40	0.50	414	F	1.50
	47.57	0.71	34.36	16.38	0.12	0.86	9.82	6.55	0.67	424	F	1.50
	48.40	0.80	29.00	20.80	0.10	0.90	8.30	8.30	1.00	441	F	1.50
	49.51	0.90	21.46	27.05	0.07	1.01	6.13	10.81	1.76	489	F	1.50
								Al_2O_3	$\frac{Al_2O_3}{CaO}$			
	44.94	0.45	51.80	1.95	0.19	0.67	14.80	0.21	0.01	431	F	1.50
	45.67	8.17	48.38	1.83	0.17	0.68	13.82	1.14	0.10	417	F	1.50
	46.74	9.13	43.39	1.67	0.16	0.68	12.40	3.32	0.25	377	S	1.50
	47.66	10.55	39.09	1.52	0.14	0.69	11.17	4.92	0.41	358	S	1.50
	48.11	12.23	36.98	1.45	0.13	0.69	10.57	5.70	0.50	357	S	1.50
B	48.95	15.38	33.03	1.32	0.12	0.69	9.44	7.17	0.70	362	S	1.50
	49.64	17.94	29.81	1.21	0.10	0.69	8.52	8.36	0.90	379	S	1.50
	49.94	19.05	28.41	1.16	0.10	0.69	8.12	8.88	1.00	388	S	1.50
	50.46	21.00	35.96	1.07	0.09	0.70	7.42	9.79	1.20	396	S	1.50
	51.10	23.39	22.95	0.98	0.08	0.70	6.56	10.90	1.50	404	S	1.50
	51.91	26.40	19.71	0.85	0.07	0.70	5.47	12.30	2.00	412	S	1.50
	52.96	30.30	14.26	0.68	0.05	0.71	4.07	14.12	3.00	422	S	1.50
								MnO	$\frac{MnO}{CaO}$			
	44.94	0.45	51.80	1.95	10.19	0.67	14.80	0.04	0.01	431	F	1.50
	43.65	0.37	40.81	1.54	12.94	0.57	11.66	2.92	0.25	394	F	1.50
	42.38	0.28	30.07	1.13	25.42	0.47	8.60	5.73	0.67	370	F	1.50
C	41.17	0.20	19.70	0.74	37.46	0.37	5.63	8.44	1.50	355	F	1.50
	40.37	0.15	12.96	0.48	45.29	0.31	3.70	10.21	2.76	348	F	1.50
	39.38	0.12	9.68	0.36	49.10	0.28	2.77	11.06	3.99	345	F	1.50
	38.86	0.05	0.17	....	60.15	0.19	0.05	13.55	271.00	348	F	1.50
							CaO + MgO	Al_2O_3	$\frac{Al_2O_3}{CaO + MgO}$			
	46.85	0.64	39.13	12.43	0.14	0.81	16.15	0.30	0.02	411	F	1.50
	47.88	4.99	35.23	11.19	0.13	0.54	14.54	2.32	0.16	373	S	1.50
D	48.87	9.32	31.21	9.92	0.11	0.51	12.88	4.34	0.33	362	S	1.50
	47.75	13.13	27.67	8.79	0.10	0.48	11.42	6.12	0.53	372	S	1.50
	50.79	17.68	23.44	7.45	0.08	0.45	9.68	8.24	0.84	391	S	1.50
	51.22	19.54	21.71	6.90	0.08	0.43	8.96	9.11	1.00	400	S	1.50

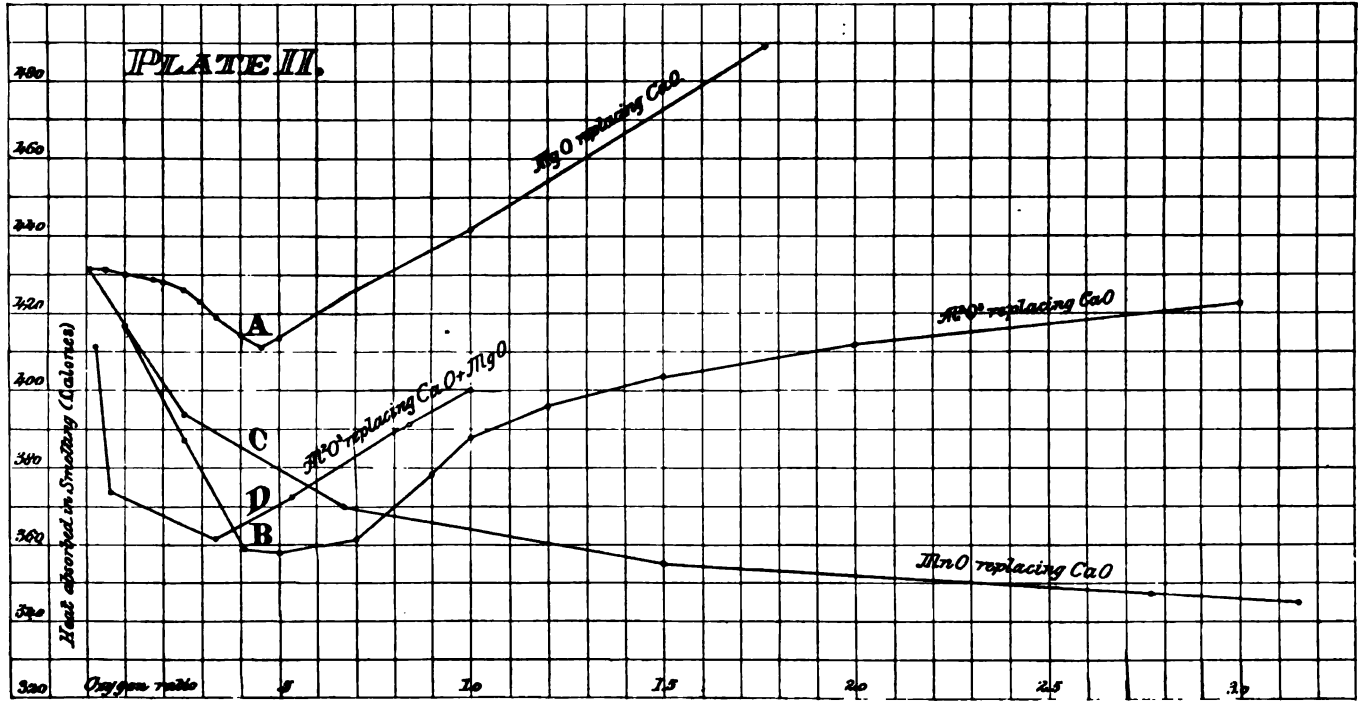
PLATE II.
480
460
440
420
400
380
360
340
320
Heat absorbed in Smelting (Calories)
Oxygen ratio
.5
1.0
1.5
2.0
2.5
3.0
MgO replacing CaO
Al2O3 replacing CaO
Al2O3 replacing CaO+MgO
MnO replacing CaO
A
B
C
D

replaced by alumina. This is quite contrary to the universal assumption that the greater the number of bases the lower the point of fusion. These curves, Plate II., indicate very clearly that basicity alone can only at best very indefinitely indicate the quality of a slag.

To bring this out still more fully we have compiled in Table No. 3 sections A, B, C, D, E, and F, in all of which slags the oxygen ratio of acid to base or bases varies from 3.0 downwards Plate III. illustrates graphically the heat requirements as modified by increasing the basicity by additions of the several bases as indicated. Curve A represents a slag composed of silica and lime only. B one composed of lime and magnesia, which have an oxygen ratio of 1. C has the same components, but the bases have an oxygen ratio of 0.50. D represents a lime slag in which the basicity is increased by increasing the percentage of alumina. E by increasing the percentage of oxide of manganese, and F the percentage of magnesia. It is much to be regretted that all these slags were not carried down to a basicity of 0.50, since most blast-furnace slags vary between 1.50 and 0.50 in basicity. It is quite evident, however, from what we have shown that bases cannot replace each other according to their oxygen equivalents without disturbing the quality of the slag, and least of all can alumina replace lime. It is further evident that oxide of manganese is most markedly different from lime and magnesia in its effect on the physical quality of the slag, and that even lime and magnesia are far from being identical. The hypothesis that the R O bases at least could be classed together and treated alike is therefore also quite misleading.

We are not prepared to say that the behavior of Professor Ackerman's artificial slags is identical with such of the same composition produced in a blast furnace; on the contrary, we are of the opinion that they are not. Nevertheless practical experience corroborates the above deductions in a sufficient measure to render

TABLE No 8.

Heat Requirements of Artificial Slags Compiled from Prof. R. Ackerman's Experiments.

	SiO_2 %	Al_2O_3 %	CaO %	MgO %	MnO %	FeO %	Oxygen % in. CoO	Oxygen % in. MgO	Oxygen Ratio. $\frac{MgO}{CaO}$	Heat Units.	Quality.	Basicity.
A	62.00	0.40	35.60	1.30	0.10	0.60	10.15	0.50	0.05	396	S	3.0
	57.70	0.40	39.70	1.50	0.10	0.60	11.30	0.60	0.05	446	F	2.5
	52.10	0.40	45.00	1.70	0.20	0.60	12.90	0.70	0.05	472	F	1.0
	44.94	0.45	51.80	1.95	0.19	0.67	14.80	0.78	0.05	431	F	1.5
B	65.10	0.60	19.50	13.90	0.10	0.80	5.55	5.55	1.00	417	S	3.0
	61.00	0.60	21.90	15.60	0.10	0.80	6.25	6.25	1.00	402	S	2.5
	55.50	0.70	25.00	17.90	0.10	0.80	7.15	7.15	1.00	456	S	2.0
	48.40	0.80	29.00	20.80	0.10	0.90	8.30	8.30	1.00	441	F	1.5
	38.50	0.40	35.30	25.20	0.10	0.50	10.10	10.10	1.00	501	F	1.0
C	64.00	0.50	25.60	9.10	0.10	0.70	7.30	3.65	0.50	402	S	3.0
	59.70	0.50	28.70	10.30	0.10	0.70	8.20	4.10	0.50	372	S	2.5
	54.20	0.60	32.60	11.70	0.10	0.80	9.30	4.65	0.50	391	S	2.0
	47.10	0.70	37.80	13.50	0.10	0.80	10.80	5.40	0.50	424	F	1.5
	37.20	0.80	44.90	16.10	0.10	0.90	12.80	6.40	0.50	483	F	1.0
								Al_2O_3	$\frac{Al_2O_3}{CaO}$			
D	62.00	0.40	35.60	1.30	0.10	0.60	10.84	0.20	0.02	396	S	3.0
	59.06	4.51	34.23	1.31	0.12	0.63	10.50	2.10	0.20	347	S	2.5
	56.76	8.95	33.88	1.31	0.12	0.66	10.43	4.17	0.40	351	S	2.0
	48.95	15.38	33.03	1.32	0.12	0.69	10.24	7.17	0.70	362	S	1.5
	40 34	28.34	28.92	1.09	0.10	0.46	9.90	11.90	1.20	377	S	1.0
	32.55	30.09	35.25	1.34	0.13	0.47	10.79	14.02	1.30	359	F	0.7
	26.61	40.61	30.87	1.71	0.11	0.40	9.46	18.93	2.00	384	S	0.5
								MnO	$\frac{MnO}{CaO}$			
E	62.00	0.40	25.60	1.30	0.10	0.60	10.15	0.02	0.05	396	S	3.0
	53.84	0.18	15.41	0.57	29.31	0.40	4.40	6.61	1.50	356	F	2.5
	47.45	0.14	11.40	0.42	39.87	0.33	3.36	8.98	2.76	357	F	2.0
	39.98	0.12	9.68	0.36	49.10	0.28	2.77	11.06	3.99	345	F	1.5
	30.84	0.09	6.66	0.25	61.85	0.21	0.90	13.94	7.34	366	F	1.0
								MgO	$\frac{MgO}{CaO}$			
F	62.00	0.40	35.60	1.30	0.10	0.60	10.15	0.50	0.05	396	S	3.9
	58.50	0.40	35.30	5.00	0.10	0.70	10.05	2.01	0.20	363	S	2.4
	53.70	0.60	35.00	9.80	0.10	0.80	10.00	3.90	0.39	389	S	2.0
	47.57	0.71	34.36	16.38	0.12	0.86	9.82	6.55	0.67	414	F	1.5

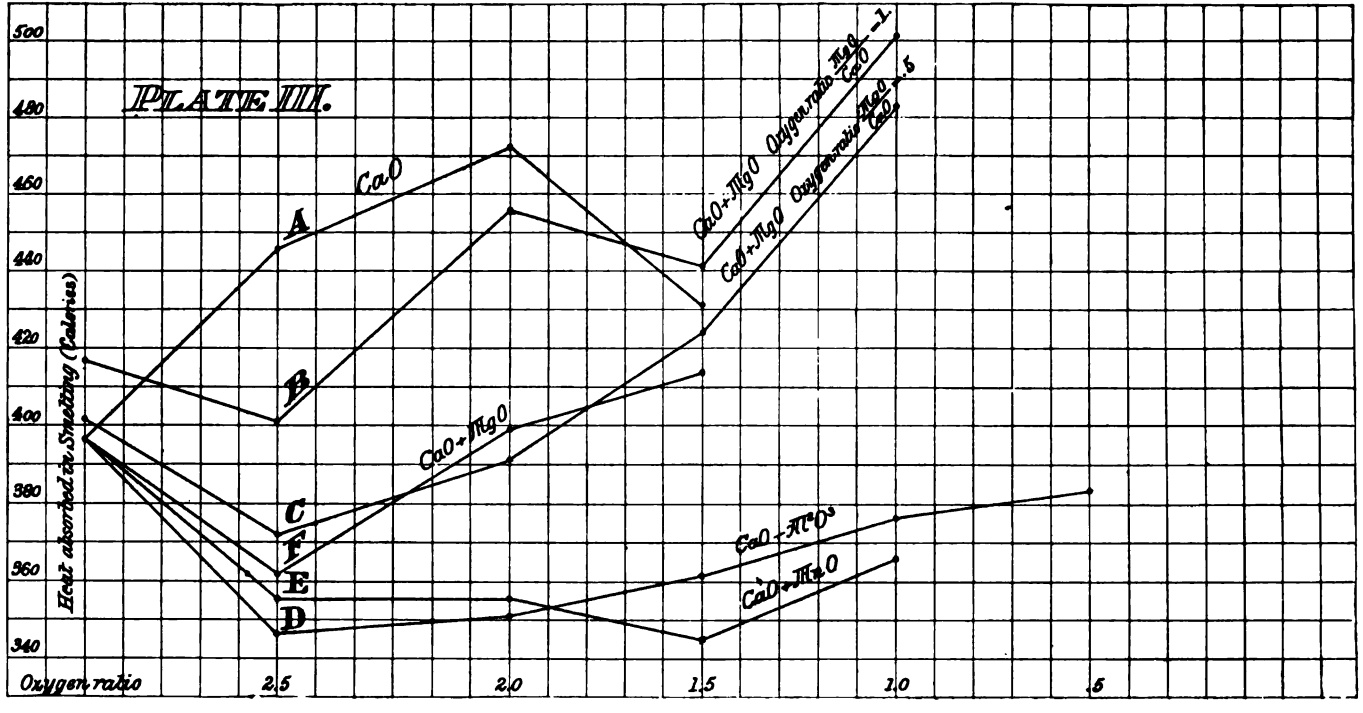
PLATE III.
500
480
460
440
420
400
380
360
340
Heat absorbed in Smelting (Calories)
Oxygen ratio
2.5
2.0
1.5
1.0
.5
CaO
A
B
C
F
E
D
CaO+MgO
CaO+MgO Oxygen ratio MgO/CaO = 1
CaO+MgO Oxygen ratio MgO/CaO = .5
CaO+Al2O3
CaO+Al2O3

them very welcome as an aid to explain why slags of the same basicity may and do behave quite differently. More such experiments are needed, and especially experiments with actual blast-furnace slags produced in the modern furnace.

COMPARATIVE TEST OF THE CALORIFIC POWERS OF WILKINSON CARBURETTED WATER GAS AND LOWE CARBURETTED WATER GAS WITH THE JUNKER CALORIMETER.*

MARTIN SHEPARD, RUDOLPH E. BRUCKNER, JOHN SCHIMMEL, JR., '96.

The use of gas for motive power in the gas engine as well as for heating has made the subject of its calorific power of paramount importance. To determine this latter, many calorimeters have been invented, all of which give more or less accurate results. Foremost among these inventions are those of Hartley and Junker, both of which possess the advantage of burning gas under a pressure a little greater than atmospheric, thus dispensing with the necessity of explosion under high pressures of oxygen. In practice the results obtained from either of these calorimeters are considered sufficiently accurate, without applying any corrections. In more refined experiments the results given by the calorimeter must be altered so as to include all corrections, including the heat units carried away by entrained moisture in the products of combustion. These corrections will be taken into consideration in the tests which follow.

The plan pursued was as follows:

The gases examined were analyzed and their constituents determined. From this the theoretical calorific power was determined, and the result compared with that obtained from the calorimeter. To eliminate errors due to variation in the composition of the gas the samples for analysis and for calorimeter tests were taken as nearly as possible at the same time. Also, to

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*Graduating Thesis.

insure an average result the mean of five experiments has been taken.

The following results were obtained for the heat of combustion for gas burned under ordinary atmospheric conditions:

HEAT OF COMBUSTION IN B. T. U. PER CUBIC FOOT OF GAS.

Gas.	Results Not Corrected for Heat Carried Off by Moisture.		Results Corrected for Heat Carried Off by Moisture.		Theoretical Heat of Comb. Calculated from Analysis. Dry Gas at 32 F. and Atmospheric Pressure.
	Dry Gas at 32° F. and Atmospheric Pressure.	Gas Saturated with Moisture at 60° F. and Atmospheric Pressure.	Dry Gas at 32° F. and Atmospheric Pressure.	Gas Saturated with Moisture at 60° F. and Atmospheric Pressure.	
1	2	3	4	5	6
Hoboken (Wilkinson).....	668.1	621.3	683.6	635.7	687.1
Jersey City (Lowe).....	738.6	686.8	754.2	701.3	749 7
Long Island City (Lowe)..	768.3	714.5	783.8	728.9	782.9

The process by which each gas is made is stated in Column 1. Column 2 gives B. T. U. per cubic foot of dry gas at the standard conditions of 32° F., and atmospheric pressure, which is taken at 760 mm. of mercury at 32° F., or (30 inches of mercury at 60° F.). Column 3 gives the B. T. U. at the standard condition of 60° F., and atmospheric pressure with the gas saturated with moisture. Columns 4 and 5 give the B. T. U. per cubic foot, accounting for the heat carried off by moisture contained in waste products from calorimeter. This is not taken into consideration in the ordinary use of many calorimeters. The correction for this moisture amounts to about 2 per cent. of the total heat of combustion. Column 6 gives the theoretical heat of combustion calculated from the analysis of the gas.

METHODS OF ANALYSIS.

From "Hempel,"* page 19, we find that analyses may be made:

1. By successive absorption of the different constituents and the volumetric determination of each.

2. By absorption and subsequent determination by titration and weighing.

3. By combustion and volumetric or gravimetric determination of the products.

The first of these methods is the most expedient and has been pursued in these tests. This requires the use of the following apparatus: A Winkler gas burette for the collection and measurement of the gas and the various absorption pipettes necessary for the reagents to absorb the different constituents. A battery and induction coil for explosion complete the outfit for the analysis. This method of analysis is superior to the other methods in several respects. The simple construction of the pieces of apparatus renders cleaning easy, also the use of a separate pipette for each reagent saves time, inasmuch as one filling of the pipette suffices for 15 or 20 experiments before fresh reagent is required. Also, the Winkler gas burette affords an extremely accurate method of measuring. Following are the results of one analysis showing the method of work:

A sample of gas is drawn into the burette over water which has been previously saturated with the gas. Time is allowed for the water to run down the sides of the tube, and a reading then taken which should be 100 c.c.

The end of the burette is then connected with a pipette containing a 10 per cent. solution of KOH. This removes by absorption the CO_2 contained in the gas. The remainder is drawn back

*"Methods of Gas Analysis," by Dr. Walther Hempel, translated by Prof. L. M. Dennis, New York, 1894.

and allowed to stand for the water to run down (this being done in each case), and a reading is then taken. For, example in the case of the Jersey City gas, Lowe process, we have:

$$100 - 97.8 = 2.2 \text{ per cent. } CO_2.$$

The illuminants are next removed by Nordhausen fuming acid, $H_2S_2O_7$, the gas being forced into a pipette containing the acid and afterward into a solution of KOH to remove any acid fumes, and the absorption determined;

$$97.8 - 85 = 12.8 \text{ per cent. illuminants.}$$

The gas is then passed into a pipette containing a solution of pyrogallic acid and K O H. This solution readily absorbs oxygen and must therefore not be exposed to the air.

Reading $85 - 85 = 0$ per cent. oxygen.

The solutions of pyrogallic acid and caustic potash were made separately and mixed in the pipette. The CO is now removed by cuprous chloride, Cu_2Cl_2. This reagent is formed by dissolving CuO in HCl. The fumes of HCl must be removed as in the other cases by KOH before a reading can be taken.

Reading $85 - 60.8 = 24.2$ per cent. CO.

The remaining constituents are:

Marsh gas, CH_4
Hydrogen, H.
Nitrogen, N.

These are treated as follows:

About 15 c.c. of the remaining gas are taken and mixed with enough air to make up 100 c.c. This is then passed into the explosion burette over water previously saturated with the gas. It is well shaken to insure a thorough mixture of the air and gas and then exploded by means of a spark from the induction coil. Time is now allowed for it to cool. A reading of the contraction is then taken.

$$100 - 77.4 = 22.6 \text{ contraction.}$$

CH_4 burns to an equal volume of CO_2, therefore the CO_2 present gives the amount of CH_4 in the residual gas. Pass into KOH and take reading.

$$77.4 - 73 = 4.4 \text{ c.c. } CO_2 = CH_4 \text{ in } 15 \text{ c.c. of gas.}$$

The proportion, $15 : 60.8 :: 4.4 : x$, gives us

$$x = 17.83\ \%\ CH_4 \text{ in the } 100 \text{ c.c. of gas taken.}$$

To find the hydrogen present:

Let C = contraction.

$D = CO_2 = CH_4$ in 15 c.c. of gas.

Then $$H = \frac{2C - 4D}{3} = \frac{45.2 - 17.6}{3} = \frac{27.6}{3} = 9.2\ \%\ H$$

in 15 c.c. of the residual gas.

The same proportion gives us 32.07 per cent. of hydrogen in the 100 c.c. of gas taken. By adding all the constituents together and subtracting the sum from 100 we get 5.02 per cent. N. The complete analysis of the Jersey City gas is as follows:

Gas.	Percentage.	B. T. U. of Constituents per Cubic Foot of Gas at 32° F.
CO_2	2.2	....
C_6H_6 (Illuminants)	2.	33.84
C_2H_6 (Illuminants)	8. (12.8)	197.8
C_2H_4 (Illuminants)	2.8	114.21
O	....	....
CO	24.20	82.59
CH_4	17.83	189.7
H	37.95	131.6
N	5.02	....
	100.00	749.74 B. T. U.

A very refined experiment is needed to separate the various hydrocarbons. The proportion of heavy to light hydrocarbons varies considerably in ordinary illuminating gas and must be determined for each gas.

The values given in column 3 are based on Thomsen's work

and presuppose that all the moisture is condensed. The following table, obtained from Professor Jacobus, gives the heat of combustion at 760 mm. pressure and 32° F.:

Gas.	Symbol.	Wt. of 1 Cu. Ft. at 32°.	B. T. U. per Lb.		B. T. U. per Cu. Ft. at 760 mm. and 32° F.	
			Vapor Condensed.	Vapor Not Condensed.	Condensed.	Not Condensed.
Hydrogen	H	.005591	62,032	52,368	346.8	292.8
Carbonic oxide.	CO	.07813	4 369	4,369	341.3	341.3
Methane.....	CH_4	.04464	23 827	21.425	1064.	956.
Ethylene	C_2H_4	.07898	21,422	20.050	1692.	1583.
Acetylene.....	C_2H_2	.07346	21.457	20,718	1576.	1522.
Benzole vapor.	C_6H_6	.22120	18.441	17,702	4079.	3916.
Propylene	C_3H_6	.11714	22,109	19,737	2473.	2312.

The following is the data observed in a calorimeter test made on a sample of the Jersey City gas taken at the same time as the sample for analysis:

Gas.		Water.		Pressure of Gas.	Meter.	Water Products of Combustion	Barometer	Temperature.
Inlet.	Outlet.	Inlet.	Outlet.					
C°	C°	C°	C°	Inches.	Liters.			
21	22	19.5	42.5	.75	54.5	....	30.75 in.	....
21	22	19.5	41.8	.75	..	....	....	71° F.
21	22	19.5	41.5	.75	....	....	. ..	....
21	22	19.5	41.5	.75	....	....	....	....
21	22	19.5	40.7	.75	61.73	....	....	....
21°	22°	19.5°	41.56	.75	7.23	....	....	...

The arrangement of apparatus is shown in Fig. 1, the gas being led first through the meter, then through the pressure regulator, and finally burned in the calorimeter. The meter was standardized by comparison with a standard two-liter flask. The gas is first passed through the meter and then collected in the flask over water. When the reading was made care was taken to have the level of the water in the flask and in the vessel in which it was inverted

the same. The meter is of the water type, and was found to be correct within the limits of observation. The pressure indicated on the regulator was that in the meter and was read in inches of water. This affords a means of ascertaining the exact amount of gas passing through the meter during a test, it being necessary to reduce all to the standard temperature and pressure.

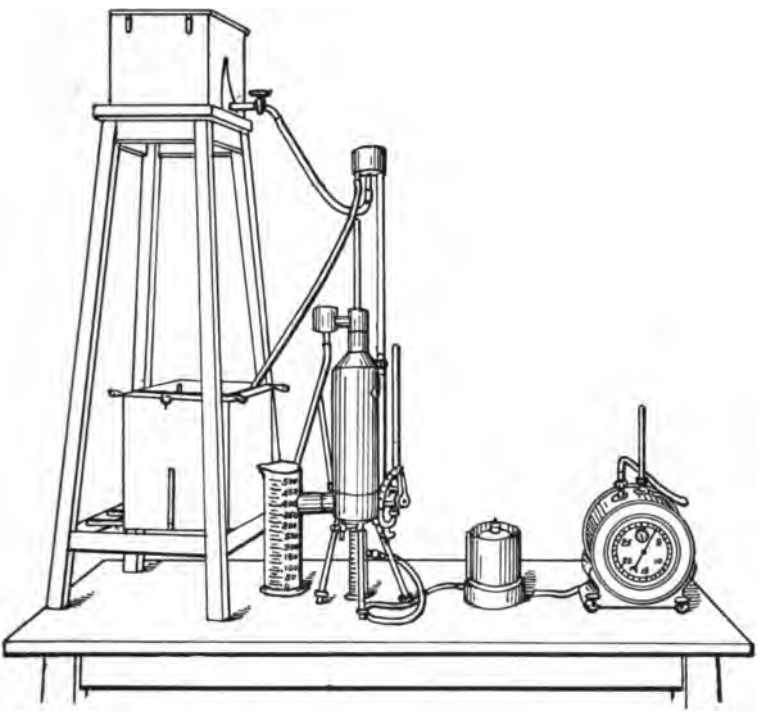

FIG. 1.

A section of the calorimeter is shown in Fig. 2. The nipple (I) is the cold-water inlet, opening into a closed gauze cylinder or strainer (2) which removes any dirt or air bubbles contained in the water. This strainer is surrounded by a cup which insures a constant head. When the water reaches the top of this cup or upper container, it is allowed to escape by the waste overflow or second

cup numbered 4. There should be a constant overflow to insure the water being at the proper height. The water leaves the upper container by the fall pipe (6), which is joined to the calorimeter by the joint (7). The quantity of water entering the calorimeter is governed by the adjustment cock (9) having a pointer moving along a graduated arc, thus affording a most accurate means of regulating the flow. After passing the cock the water passes the cold-water thermometer (12). This gives column 3 of the preceding table, namely, the temperature of the inlet water. The tube (13) by which the water enters the calorimeter as well as the thermometer well is surrounded by an air jacket to render radiation or absorption of heat by the water impossible. The water next passes through the perforated spreading ring (14) by which it is led into the water-jacket (15) and (16) surrounding the cooling tubes (30). The water next comes in contact with the baffle-plates (17) provided with cross-slots. These form the lower portion of the hot or exit water thermometer well, and insure a thorough mixture of the water. After passing the baffle-plates the exit temperature is taken, the water then escaping by the lower overflow (18) into the lower container (19) and thence to the hot-water overflow (20), and by the hot-water nipple (21) into the collecting vessel. In all these tests a

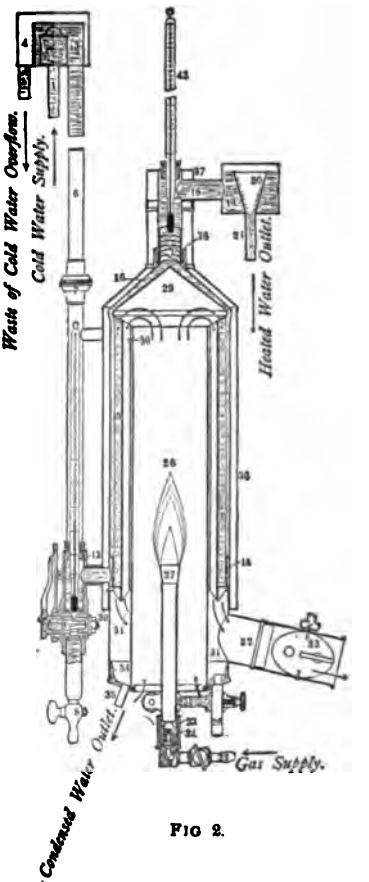

FIG 2.

two-liter graduate was employed, and the duration of the test was the time required to fill this vessel. This graduate was standardized by means of the same standard two-liter flask, and found to be correct. The gas, after leaving the meter and regulator, passes by the nipple (22) into the burner, which is a very carefully made Bunsen burner capable of being raised and lowered by means of the clamp (25) sliding along the burner holder (26). The burner is supplied with several gas nozzles of various sizes, by means of which the flame may be modified. The burner consists of a tube surmounted by a burning cap (27) of steel, made with three orifices which spread the flame equally towards all sides of the calorimeter. The space (28) is the combustion chamber, open at the bottom to allow the entrance of air necessary for combustion. The heated products of combustion rise to the roof (29) of the combustion chamber, and thence to the cooling tubes (30) around which the water circulates. These cooling tubes open or empty into the receiver for combustion gases (31). The gases when they reach this point are totally deprived of their heat, that is, they are at the same temperature, or nearly the same, as the entering unburnt gas. The combustion chamber communicates by means of the outlet for combustion gases (32) with the external air. This passage, which is elliptical in shape, is provided with a throttle (33) by means of which the exit gases may be controlled. No. 34 is a brass base ring. The hydrogen, as well as some of the hydrocarbons in combustion, forms water which is condensed on coming in contact with the cold walls of the calorimeter and collects in drops on the inside walls. This water is part of the burnt products and is collected and measured in a graduate placed under the drip (35) called the condensed-water outlet. The drip (8) is so placed that it will drain all the water out of the calorimeter when it is required. All the parts which could in any way absorb or radiate heat to the detriment of the experiment are completely insulated by air-jackets. The thermometers were standardized at the Grosherzogl. Saechs. Prüfungsanstalt für Glasinstrumente in

Ilmenau, Germany. All corrections given in the report of each thermometer were applied in these tests; in no case did the error exceed 0.1 of one degree.

CALCULATIONS OF CALORIMETER TEST OF JERSEY CITY GAS.

From data already given we have:

Inlet water, 19.5° C.; corrected, 19.4.

Outlet water, 41.50° C.; corrected, 41.46.

Difference 22.06° C., which is the range through which the water was raised during the test.

Letting H = calorific value of 1 cu. ft. of gas at 32° F. in B. T. U.

W = quantity of water in liters.

T = difference in temperature in degrees C.

G = quantity of dry gas used reduced to 32° F. in cu. ft.

$$H = \frac{W\,T}{G}\,3.968.$$

When 3.968 is a constant factor to change from calories to B. T. U.,

$$W = 2. \qquad T = 22.06. \qquad G = .237.$$

$$H = \frac{2 \times 22.06}{.237} \times 3.968 = 738.6 \text{ B. T. U.;}$$

this must be corrected for heat carried in the moisture entrained in the waste products and for the difference of temperature of inlet and outlet gases.

The value of $G = .237$ cubic foot is the corrected value, the actual meter reading being .255 cubic foot. The method of correction for obtaining this figure was as follows:

Let meter reading of gas saturated with moisture $= M$. Temperature at meter in degrees F. $= t$.

Pressure in inches of water at meter $= p$.

Height of barometer (actual) $= h$ inches.

Height of barometer (corrected to 32° F.) $= h_0$.

$$h_0 = h - hm\,(t - 32)$$

where m = coefficient of Hg per degree F. = .0001.

$$h_0 = 30.75 - (30.75 \times .0001)\,(71 - 32) = 30.63.$$

Equivalent of pressure p in inches of Hg at 32° F. $= h_0'$.

$$h_0' = p.\ \frac{29.922}{33.947 \times 12} = .05,$$

where 29.922 in. = height of Hg. corresponding to one atm.

33.947 ft. = height of water corresponding to one atm.

Total pressure of gas in passing through meter $= h_0 + h_0'$ of mercury at 32° F. Gas is saturated with moisture and the tension of vapor in inches of mercury at 32° F. $= h_0''$

Actual net pressure of gas in passing through meter

$$= h_0 + h_0' - h_0''.$$

Correction for pressure

$$= \frac{h_0 + h_0' - h_0''}{29.922}$$

Correction for temperature to reduce to 32° F. $= \frac{460 + 32}{460 + t}$

Total correction by which actual cubic feet registered by meter should be multiplied to reduce to amount of *dry* gas at the normal atmospheric pressure of 29.922 in. or 760 mm. of mercury and at 32° F.

$$= \frac{h_0 + h_0' - h_0''}{29.922} \times \frac{460 + 32}{460 + t}$$

For saturated gas at a temperature of 60° F., which is another standard condition sometimes used, the following formula applies:

To reduce B. T. U. per cubic foot of dry gas, at the same

pressure and at 60° F., multiply B. T. U. per cubic foot to dry gas at 32° F. by $\frac{492}{460+60}$ or by $\frac{492}{520}$

To reduce to B. T. U. per cubic foot of gas saturated with moisture at 60° F. multiply the B. T. U. per cubic foot of dry gas at 60° F. by the following fraction:

$$\frac{30-[.517\{1+.000103\,(60-32)\}]}{30}=\frac{30-.518}{30}=.9827$$

Total correction to reduce from dry gas at 32° F. to a gas saturated with moisture, at 60° F., and barometric pressure of 30 inches at 60° F., which is equivalent to a pressure of 29.922 inches at 32° F. or to the pressure of 1 atmosphere, = product of the above factors,

$$=\frac{492}{520}\times .9827=.9298.$$

The heat of combustion for dry gas at 32° F. and 760 mm. pressure was 738.6 B. T. U.; this multiplied by the constant .9298 gives 686.8 B. T. U. for gas saturated with moisture at 60° F.

CORRECTION FOR HEAT CARRIED OFF IN VAPOR CONTAINED IN PRODUCTS OF COMBUSTION.

Calculation of Per Cents. by Weight.

	Analysis by Volume of Gas.	Density.	Per Cent. by Volume × Density ÷ 100.	Per Cent. by Weight.
CO_2	2.2	1.524	.03352	5.22
C_6H_6 (Illuminants.)	2.	2.77	.05540	8.63
C_3H_6 (Illuminants.)	8.	1.451	.11608	18.08
C_2H_4 (Illuminants.)	2.8	.978	.02738	4.26
O	....	1.106	....	....
CO	24.2	.973	.23546	36.68
CH_4	17.83	.559	.09966	15.52
H	37.95	.069	.02618	4.06
N	5.02	.972	.04879	7.55
	100.	....	.64247	100.00

Calculations of Weights of H, C, and O.

	Analysis by Volume of Gas.	Per Cent. by Weight of H.	Per Cent. by Weight of C.	Per Cent. by Weight of O.
CO_2	2.2	....	$\frac{12}{44} \times 5.22 = 1.42$	....
C_6H_6 } Illuminants.	2.	$\frac{6}{78} \times 8.63 = .66$	7.97	3.8
C_2H_6 } Illuminants.	8.	$\frac{6}{30} \times 18.08 = 2.58$	15.5	...
C_2H_4 } Illuminants.	2.8	$\frac{4}{28} \times 4.26 = .61$	8.65	....
O	....	....	....	....
CO	24.2	....	$\frac{12}{28} \times 36.48 = 15.63$	21.05
CH_4	17.83	$\frac{4}{16} \times 15.42 = 3.85$	11.57	....
H	37.95	4.06	....	....
N	5.02	....		
	100.	11.76	55.74	24.85

The pounds of oxygen required to burn the hydrogen in one pound of gas, thus forming water, is $.1176 \times 8 = .9408$.

The pounds of oxygen converted to water per pound of carbon

$$= \frac{.9408}{.5574} = 1.68$$

Pounds of oxygen in gas per pound of carbon $= \frac{24.85}{55.74} = .445$.

Analysis of Products of Combustion.

By Volume.	Density.	Per Cent. of Volume × Density ÷ 100.	Per Cent. by Weight.	Per Cent. by Weight of Carbon.	Per Cent. by Weight of Oxygen.
$CO_2 = 6.0$	1.524	.09144	8.9	$\frac{12}{44} \times 8.9 = 2.4$	....
O $= 11.02$	1.106	.1218	11.9	...	6.5
N $= 82.98$	.972	.8065	79.19	....	11.9
100.	....	1.01974	99.99	2.4	18.4

This is the mean of five analyses. Oxygen in products of combustion per pound of carbon $= \frac{18.4}{2.4} = 7.66$ pounds.

Oxygen that has been converted to water per pound of carbon $= 1.68$ pounds. Total oxygen per pound of carbon $= 7.66 + 1.68 = 9.34$ pounds.

To find the oxygen supplied by air we must deduct the oxygen which is in the gas burned.

Oxygen furnished by air per pound of carbon $= 9.34 - .45 = 8.89$ pounds. Air entering calorimeter per pound of carbon

$$= \frac{8.89}{.23} = 38.65 \text{ (0.23 = \% by wt. of O in air) pounds.}$$

Pounds of air entering calorimeter per pound of gas burned

$$= \frac{38.65 \times 55.74}{100} = 21.54.$$

The cubic feet of air entering calorimeter per cubic foot of gas burned, neglecting the moisture contained in same,

$$= 21.54 \times 0.642 = 13.83 \text{ cubic feet.}$$

To determine volume of products of combustion:

Weight of N in air entering calorimeter per pound of carbon

$$= 38.65 - 8.89 = 29.76 \text{ pounds.}$$

Weight of N in gas per pound of carbon

$$= \frac{7.55}{55.74} = .13 \text{ pound.}$$

Total nitrogen $= 29.76 + .13 = 29.89$ pounds per pound of C.

This should equal the figure calculated from the products of combustion $= \frac{79.19}{2.4} = 32.9$, pounds which is sufficiently close for the present purpose.

Employing the quantity 29.89, we have for the total weight of the products of combustion per pound of carbon,

N =	29.89	pounds.
O =	7.66	"
C =	1.00	"
	38.55	"

The weight of the products of combustion per pound of gas

$$= \frac{38.55 \times 55.74}{100} = 21.48 \text{ pounds.}$$

The density of the products of combustion is 1.02.

The products of combustion in cubic feet per cubic foot of gas burned, neglecting volume of vapor of water,

$$= \frac{21.48 \times .642}{1.02} = 13.5 \text{ cubic feet.}$$

The temperature of air entering the calorimeter = 82° Fahr. The volume of one pound of steam at this temperature is 602 cubic feet; its latent heat is 1,049 B. T. U. per pound and its pressure per square inch .54. The weight of steam carried off in products of combustion, per cubic foot of gas burned, is given by the formula:

$$\begin{array}{l}\text{(Volume of 1 pound of saturated steam at temperature of air.)}\end{array} \times \begin{array}{l}\text{(Weight of moisture present in pounds.)}\end{array} = \frac{\text{(Volume of dry air in mixture at atmospheric pressure.)}}{\text{(Observed atmospheric pressure—pressure of saturated steam at temperature of air.)}} \times \begin{array}{l}\text{Observed atmospheric pressure.}\end{array}$$

In which the second parenthesis = x.

This equation holds because for air which is saturated with vapor the total volume of the dry air, if at atmospheric pressure, will be made greater by the presence of the moisture, so that the final volume is equal to the volume that would be occupied by the steam present in the air if it were saturated at the given temperature.

The volume of steam present in the air would be 602 x. The pressure of the mixture of dry air and steam is 14.8 pounds per square inch, so that the pressure of the dry air in the mixture is 14.8 — .54 pound, per square inch. The total volume of the dry air after mingling with the steam will therefore be

$$102\ x = \frac{\text{Vol. of dry air, at atmos. press., per cu. ft. of gas} \times 14.8}{14.8 - .54}$$

$$x = \frac{13.5 \times 14.8}{602\ (14.8 - .54)} = .0232$$

Dry bulb thermometer, 69° C.

Wet bulb thermometer, 48° C.

Degree of humidity, .33

The vapor x' in the entering air per cubic foot of gas burned will $= \frac{.33\ (13.83 \times 14.8)}{602\ (14.8 - .54)} = .0078.$

The weight of vapor in the gas burned, which is saturated with moisture, is $\frac{1}{602} = .0016$ pound per cubic foot.

The total moisture entering the calorimeter per cubic foot of gas burned will therefore be .0078 + .0016 = .0094 pound.

Excess of the moisture in the products of combustion per cubic foot of gas burned is .0232 — .0094 = .0138 pound. The latent heat in this vapor equals .0138 × 1,049 = 14.5 B. T. U. This quantity is added to the result given by the calorimeter, and amounts to about 2¼ per cent. of the total heat.

The B. T. U. as given by the calorimeter for dry gas at 32° were 756.4; this reduced to saturated gas at 60° F., which is the commercial standard, gives 738.6 × .9298 = 686.8. Adding 14.5 B. T. U. to this we have 701.3 B. T. U. Reducing to dry gas at 32° F. we have 701.3 ÷ .9298 = 754.2 B. T. U. The corresponding figure calculated from the analysis was 749 7 B. T. U., or there is a difference of 4.5 B. T. U. or .5 per cent. of the total heat of combustion.

The outlet gas and inlet air, being practically at the same temperature, no correction is necessary.

Ordinarily there will be ample moisture formed by the hydrogen in the gas to completely saturate the air.

The foregoing method of correcting for the heat carried off in the products of combustion was given us by Professor Jacobus.

Long Island City Gas—Lowe Process.

Gas.		Per Cent. by Volume.	B. T. U. per Cubic Foot.	Constituents Per Cent. B. T. U. per Cubic Foot.
CO_2		.6	....	....
C_6H_6	Illuminants	2.	4,079.	81.58
C_2H_4	Illuminants	6.	2,478.	148.38
C_3H_6	Illuminants	8.	1,692.	145.36
O		.4	....	....
CO		23.	341.3	78.5
CH_4		20.8	1,064.	221.3
H		34.	346.8	117.9
N		5.2	....	....
Theoretical B. T. U. per cubic ft.....				782.9

Calorimeter Test—Long Island City.

Water.		Gas.		Meter.	Time.	Pressure.	Products in Water.	Barometer Temperature.
Inlet.	Outlet.	Inlet	Outlet.					
C	C	E	C	Cu. Ft.				
11.	28.3	55.5	12	.192	....	.22	....	....
11.	28.4	55.5	12	....	....	.22	....	30.22 In
11.	28.5	55.5	12	....	....	.22	...	66° F.
11.	28.5	55.5	12	....	....	.22	....	....
11.	28.6	55.5	12	....	....	.22	....	...
11.	28.6	55.5	12	....	....	.22	4 c.c.	....
11.	28.6	55.5	12	.192	4'41½"	.22 In.	4 c.c.	...

The following are corrected values—

Outlet water, 28.5 °F.
Inlet " 11. "
Diff. 17.5 "

$$\frac{17.5 \times 2}{G} \cdot 3.968 = \text{B. T. U.}$$

Correction for G gives us $G = .181$ cu. ft.

$$H = \frac{17.5 \times 2}{.181} \cdot 3.968 = 768.3 \text{ B. T. U. per cu. ft.}$$

Correction for heat in moisture 14.4 B. T. U. at 60° F.

768.3 + 15.5 = 783.8 B. T. U. at 32° F. and 760 mm.

768.3 × .93 or 714.52 + 14.4 = 728.9 B. T. U. at 60° and 760 mm. pressure.

The standard meter of the Long Island City Gas Co. was used in the above test.

Hoboken Gas.—Wilkinson Process.

Gas.		Per Cent. by Volume.	B. T. U. per Cubic Foot.	Constituents Per Cent. B. T. U. Cubic Foot.
CO_2		1.8	....	....
C_6H_6	Illuminants	1.	4 079	40.8
C_2H_2	Illuminants	2.4	2,473	59.4
C_2H_4	Illuminants	11.	1,692	186.1
O		....	....	....
CO		23.6	341.3	80.5
CH_4		18.2	1,064	193.6
H		36.5	346.8	126.6
N		5.5	....	....
Theoretical B. T. U. per cubic ft....				687.1

Calorimeter Test.

Water.		Gas.		Meter.	Pressure of Gas.	Products in Water.	Barometer Temperature.
Inlet.	Outlet.	Inlet.	Outlet.				
16.7	43.2	18.9	19	30	.85	....	30.342 in
16.7	43.1	18.9	19	....	.85	....	73° F.
16.7	43.2	18.9	19	..	.8	. ..	....
16.7	43.3	18.9	19	....	.8	...	....
16.8	43.3	18.9	19	....	.8	....	....
16.9	43.3	18.9	19	39.7	.85	.8	....
16.75	43.24	18.9	19	9.7	.825	....	....
16.75	43.27	18.9	19	9.77	.825	.8 c.c.	Corrected.

Outlet water, 43.27 °F.

Inlet water, 16.75 "

Diff., 26.52 "

$\frac{26.52 \times 2}{G} \cdot 3.968 =$ B. T. U. per cu. ft.

9.77 liters of gas used. 1 liter = .0353 cu. ft.

$9.7 \times .0353 = .342$ cu. ft.

Corrected value for G equals .315 cu. ft. at 32° F. 760 mm.

$H = \frac{26.52 \times 2}{.315} \cdot 3.968 = 668.1$ B. T. U.

Correction for heat in moisture 15.5 B. T. U. at 32° F.

14.5 corrected to 60° F. and 30 in. of Hg. pressure = 14.4 and to 32° F. = 15.5.

$668.1 + 15.5 = 683.6$ B. T. U. dry and at 32° F.

This reduced to 60° F. and saturated, gives

$668.1 \times .93 = 621.3 + 14.4 = 635.7$ B. T. U.

Theoretical B. T. U. calculated from gas analysis at 32° F. = 687.1 B. T. U.
By calorimeter 683.6 B. T. U. } Dry and at 32° F.

In none of the tests was the difference between the results by the calorimeter and those calculated from the analysis greater than 1 per cent., provided the latent heat of the vapor in the products of combustion is included. The results obtained directly by the calorimeter vary from 2 to 3 per cent. from the calculated quantities if the heat carried away by moisture in the waste products is not accounted for.

ON THE FLOATING OF METALS AND GLASS ON WATER AND ON OTHER LIQUIDS.

BY ALFRED M. MAYER.

In the July, 1896, number of the INDICATOR, under the head of "Institute Notes," is a short account of the floating of aluminum rings on water. This was written soon after these phenomena were observed by me, and as the rings used were chemically clean, and as all treatises on physics that I have read state that to float a metal on water the surface of the metal must be greased, I naturally supposed that the flotation of aluminum was a property peculiar to this metal.

I soon found, however, that all metals from platinum of a density of 22 to magnesium of a density of 1.71 floated on water *when their surfaces were chemically clean.*

This fact I also regarded as not generally known; but on looking into the literature of the subject of the flotation of metals, I found that the older writers do not speak of the necessity of greasing the surface of a metal to make it float. When this erroneous notion was introduced into our books on physics and then sent down from one treatise to another, I have not been able to determine.

The floating of a metal on water was first observed in 1575, by Norman, an instrument maker of London, the man who discovered the dip of the magnetic needle.

Descartes, in *Les Météores*, Leyden, 1638, says:* La superficie de l'eau est beaucoup plus malaysée a diuiser que n' est le dedans, ainsi qu' on void par expérience en ce que tous les corps assez petits, quoyque de matière fort pesante, comme sont de petites aiguilles d' acier, peuvent flotter et estre au-dessus, lorsequ 'elle n' est

*I give this quotation in the orthography of his time.

point encore diuisée, au lieu que lorsequ 'elle l'est, ils descendent insque au fonds sans s' arrester.

The next paper on the subject is by " M. Petit le Médecin," published in the Memoirs of the Academy of Science, Paris, 1731, in which the author states that the reason why a metal floats on water is that it is kept from touching the water by a film of air which coats the surfaces of all metals. I think that M. Petit makes good his statement, for he shows that on heating a metal it no longer floats, but sinks. He makes no mention whatever of having previously greased the wires and sheets of metal with which he experimented.

Rumford, in 1807, published a paper in the Memoirs of the Academy of Science, of Paris, in which he attempts to show that a film of air does not exist on floating metals. I do not think that he makes good his opinion, for the only experiments he makes to sustain his opinion are those in which water is covered with ether, or with turpentine, and small spheres of tin and of mercury, allowed to fall through the supernatant liquid, are retained by the surface of the water, which takes the form of sacs, which support and partly inclose the spheres.

It may be of interest to the readers of this journal to have an account of the researches I have made on the flotation of metals and of glass.

A rod of aluminum of one-seventh inch in diameter made into a ring of 2½ inches in diameter floats on water. This ring weighs 5.6 grams.

If over this floating ring vapor of ether be poured, by tilting over the water an open bottle containing ether, the ring moves rapidly to and fro in a tremulous manner and then sinks, because the vapor of ether lessens the surface tension of the water.

Rings were made of aluminum, iron, tin, copper, brass, and German silver. The wire of these rings is one millimeter thick and the rings are about 50 millimeters in diameter. The axis of the

wire of a ring is in a plane; in other words, the rings are flat. Each of these rings has soldered to it a thin wire along a diameter and raised above the plane of the ring. On this wire is cemented a platform of thin metal. These rings are highly polished and are chemically clean.

On loading one of these floating rings, by gradually adding weights on its platform, the ring sinks deeper and deeper below the general surface of the water, till, finally, having sunk 5 millimeters, it breaks through the depressed surface. On the form of this depressed surface (which I have plotted) depends the amount of weight per centimeter of circumference of the ring required for the ring to break through the surface of the water. This weight, in the cases of the rings mentioned, is, on the average, about 0.160 gram per centimeter, or about double the surface tension of the water; because tangents to the depressed surface of the water, at the points where the rupture occurs, are vertical, or very nearly vertical, and the upward hydrostatic pressure on the ring is slight.

Similar experiments have been made with floating disks of metal, where, also, tangents to the points of rupture of the depressed water surface are vertical, or nearly so.

The conditions of equilibrium in the case of a weighted disk, which is just on the point of breaking through the surface of the water, is

$$W = P + T,$$

in which W = weight in grams of disk + weight added to disk to cause it to break through the surface of the water;* P = the upward hydrostatic pressure on bottom of disk in grams per square centimeter; T = the vertical resultant of tension of water-surface along the whole circumference of disk.

In the case of a weighted floating ring we also have

$$W = P + T,$$

* To cause a disk of 5 centimeters in diameter to break through the surface of water, $W = 11 +$ grams.

but in this case $T =$ the vertical resultant of tension of the two opposite surfaces of the depressed water attached to the ring.

Therefore, A, the capillary constant, or tension of water-surface in grams per centimeter, will, in the case of the disk, be

$$A = \frac{W - P}{circ.};$$

and in the case of the ring,

$$A = \frac{W - P}{circ.'}$$

In these formulæ *circ.* is circumference of disk, and *circ.'* the circumference of the axis ring.

A, thus computed from accurate measurements of W and of P, agrees closely with the best determinations of that constant.

In the present stage of the research I am inclined to hold the opinion that the flotation of metals and of glass depends on a film of air which is condensed on their surfaces. The following experiments seem to sustain this opinion. If a ring made of platinum. wire four-tenths millimeter thick, which readily floats on water, is heated to redness and as soon as cold is placed on water, it sinks Also, when withdrawn from the water and wiped dry it again sinks when placed on the water; but after the same dried ring remains about a quarter of an hour exposed to the air, then it will float. If the platinum ring, after having been heated to redness, remains in the air about a half hour and then is placed on the water it floats.

Glass behaves in a similar manner to platinum. If a rod of glass, recently drawn out in a spirit flame and just cold, is placed on water it sinks. After a freshly made rod has remained exposed to the air about a quarter of an hour it will float. If a recently made glass rod, which has just sunk in water, be withdrawn, wiped dry and exposed to the air for a quarter of an hour, it will float. The glass rods used in these experiments are 1 millimeter thick and 4 to 5 centimeters long.

Under certain conditions the ratio of the weights required to make a platinum ring break through the surface of water and through the surface of another liquid is the ratio of the surface tension of water and that of the liquid. This ratio is 1 : 1.09 in the case of water and a solution of chloride of sodium of density 1.2. Taking .076 as the surface tension of water we have 1 : 1.09 = .076 : .0828. Platinum is used for such experiments, because it is not oxidizable and is chemically inert to nearly all liquids.

I reserve for a more extended paper an account of the many facts I have observed during experiments on floating disks and rings of metals. That paper will also contain a discussion of the relation of these facts to the capillary theory of Laplace and Gauss.

ADDRESS TO THE SENIOR CLASS AT THE OPENING OF THE TERM, SEPTEMBER 23, 1896.

BY PROF. DE VOLSON WOOD.

What is the use of Thermodynamics? The motives which prompt this question are various, but it probably arises chiefly from those who desire to know its utilitarian ends, its money-making power. When the chief aim of study is to acquire knowledge which can be promptly transmitted into gold or even into silver, one is robbed of more than half the pleasures of knowledge and of nearly all the rich culture that ought to result from its acquisition. The form of this question is not new. Nearly forty years ago I was asked by students: What is the use of Descriptive Geometry. The answers were various, depending upon the point of view, such as: It is a good subject for hard study since it compels one to think and thus develop his mental powers. Wait until you are older and the question will answer itself. It is in the course and must be studied if one would graduate, all of which was correct, but rather evasive and unsatisfactory. Finally, it was said, that it was of use in enabling a draughtsman to make different views of machines, and enabled a mechanic to construct a machine from the drawings; and the designing architect to make drawings from which the builder could make a house. It might further be said to be a science, which led to methods of making geometrical perspective, spherical projection, and the determination of shadows, and solutions of other graphic problems.

The evasive answers given above, together with the fact that it is a science, apply with equal force to Thermodynamics, and may satisfy the student who studies for the love of it, but the utilitarian student desires to know if it can be applied in practice. It would

be passing strange if it could not be so applied, for all knowledge has its practical uses.

Thermodynamics is a formulated science of heat. It is founded upon the results of the best experience and experiment. After a series of careful experiments, sometimes extending over years, men of ability drew conclusions stating the results in the form of laws, after which the laws themselves were examined and tested, resulting either in their overthrow or confirmation. In this way several laws have been established; they represent the wisdom of ages. The student of the present day accepts them as unquestioned verities, and from their discussion deduces all the particulars which are necessary for his purpose. This is the scientific way, and its use results in a great saving of time and energy in obtaining a knowledge of science. The effort is for truth, and great faith is exercised in the integrity of Nature and of the investigator.

To illustrate; the law of Mariotte (1769) (or of Boyle, 1760), according to which the volume of gas varies inversely as the pressure was deduced from experiments made directly upon gases in which the pressure varied slowly, thus producing no perceptible effect upon the temperature. Next, Gay Lussac (1802) (or Charles, 1787) found by experiment that the volume increased with the temperature, the pressure being constant, or that the pressure increased with the temperature, the volume being constant. The laws of Mariotte and Gay Lussac were then combined into one expression of the form,

$$p\,v = R\,\tau,$$

in which p is the pressure upon a unit area, v the volume of unity of weight, τ the absolute temperature, and R a constant to be determined for each particular gas. It is scarcely half a century since the final form given above was established, for before that the term "absolute temperature" was not known in this science. For a long time it was supposed that the above law was an exact law of Nature for such substances as air, oxygen, nitrogen, and hydrogen;

but more refined experiments have shown that it is at least only a very close approximation to the actual law that for very low temperatures accompanied by high pressures it fails entirely. So now we begin the science by assuming the above equation to represent the law of *an ideally perfect gas*, and from it deduce the laws of Mariotte and Gay Lussac. This is the same process that is employed in analytical mechanics—bodies are defined as hard, elastic, fluid, etc.—and the results deduced compared with what is found for actual bodies under similar conditions.

Similarly, the first law of thermodynamics—that heat and mechanical work are mutually convertible in a definite ratio—was first foreshadowed by Count Rumford in 1778, and Davy in 1779, after which there were discussions and deductions, giving rough approximations of the ratio—a gradual approach to the truth—until 1843, when Dr. Joule, of Manchester, England, began his memorable experiments, which, after some seven years of experimenting, resulted in declaring that one British thermal unit was equivalent to 772 foot-pounds of work. More recently, a review of that work, and further experiments, have resulted in fixing upon 778 as the more probable value.

Let it be observed that these laws—and all other so-called laws of Nature—are not determined from prior principles or axioms like propositions in geometry, but by experiment, observation, and deduction. If these remarks be fully appreciated it will be easy to understand how the second law—or the expression for the efficiency of the Carnot engine—was established. To discuss this presupposes knowledge which it is assumed you do not yet possess, so I will not consider it, but leave it to be taken up during our future study.

Some of the results of this science are:

1. It has shown the directions in which the efficiency of heat engines may be improved—by increasing the range of temperature through which the fluid is worked.

2. It determines the efficiency of an engine compared with the

calorific power of the fuel. This could not have been done prior to the determination of the mechanical equivalent of heat.

3. It generalizes and systematizes the study of all heat engines—steam and other vapor engines, gas and hot-air engines, compressors, injectors, etc.

4. It has led to the determination of certain properties of saturated vapors.

5. It has led to certain graphical representations which present certain principles more clearly to the mind.

6. By it one may design, thermodynamically, the volume of the cylinder to do a given amount of work, determine the pounds of fuel and the pounds of steam. In practice there are wastes which must be determined practically and allowed for before the thermodynamic engine will be a practical one.

7. It gives a definite solution to certain problems in refrigeration.

8. It has been a means of discovery; as, for instance, by it was made the first correct determination of the specific heat of air; the liquifaction of vapor due to expansion in a non-conducting cylinder; the volume of a pound of vapor; the specific heat of steam and other superheated vapors at constant volume; the heat of vaporization of ammonia; the approximate value of the specific heat of liquid ammonia; the lowering of the melting point of ice due to pressure; and is used in the solution of many problems which might be resolved by other means.

9. It is related to some of the higher and refined problems of physics. What elements seem more unrelated than the mechanical equivalent of heat and the velocity of sound in air—or other gas—and yet they are definitely connected by an algebraic equation—they are so definitely connected that they cannot be separated. Surely there is poetry in science even if takes a mathematical genius to find it.

10. By a study of heat in all its phases, of which the mechanical theory is one, a student is led the more to appreciate the importance of saving heat and of means for avoiding wastes; and it gives him an advantage, in the management of steam, over one whose chief business it is to bore cylinders and make pistons and connecting rods.

A student in engineering cannot be indifferent towards a science which yields such results. It is not claimed that one thoroughly versed in this science can design a good engine—it is only one of the elements of knowledge. To take an illustration from another science, the stress diagram is only one of the elements in bridge design; but students are taught the theory of stresses in the lecture-room. The inexperienced graduate is not intrusted with the designing of bridges, although he may do valuable work in some parts of the design. Bridges are designed by men who, in addition to theoretical knowledge, have acquired a knowledge of details by practical experience, and the bridge is built as a business. Similarly, engines are built as a business, designed by men who have a knowledge of details; and yet the theory is taught in the lecture-room.

Just here I found the following in a technical journal:

"The fundamental trouble in much of the current technical education is that the student wants to learn enough to get an easy job. This idea makes shipwrecks of many lives. It is not until after technical education has been completed that many discover their unfitness for their life work. The easy college work is deceptive to students, while the hard and rough shop-work tests and tries and determines qualifications in a more unmistakable way."

This is not a criticism or reflection upon true, substantial education; but it justly condemns humbuggery in education—the pretending to impart power to a young man by lecturing him; or the supposed advantage of attending school without study. Education

like character, is, of slow growth, acquired by daily effort. The school is for study, and if not attended to when in school the time and opportunity are lost forever. If one has not discovered truth by study, he knows nothing of the pleasures and joy of the real student. By this I do not mean that it is necessary to discover a law of Nature heretofore unknown, but simply the working out for himself some question in science which was obscure before. In everything he injures himself who does not do his best. The business world, into which most, if not all, must enter, is a merciless crucible, consuming the dross, and leaving only that which is true. I entreat you to labor earnestly for that education which will endure.

EXPERIMENTS TO DETERMINE THE ECONOMY OF OPERATING A NON-CONDENSING STEAM ENGINE, USING A MIXTURE OF STEAM AND COMPRESSED AIR.*

GRADUATING THESIS.

BY ROBT. E. LEBER, GEORGE HEWITT, HARDING BENEDICT, '96.

The engine used in the experiments was a "Buckeye" of the horizontal type, and was employed in furnishing a portion of the motive power for the machine shops of the Stevens Institute of Technology.

The engine was put in perfect condition by reboring the cylinder, fitting new piston rings, rescraping the valves and valve seats, repacking, etc., thus making it perfectly tight.

The engine dimensions were as follows:

Cylinder diameter	$7\frac{5}{32}$ inches.
Piston-rod diameter	1 "
Stroke	14 "
Clearance	3 per cent.

The engine is regulated by a flywheel governor, but in order to obtain a definite cut-off the governor was fastened to produce a cut-off of about one-fourth, while the variation of the shop load was taken up by a small upright engine controlled by a rotary governor.

*Previous to the period when the performance of steam engines was generally studied by aid of the indicator cards, and a measurement of the actual weight of steam used, the admixtion of air with the steam supplied to engines was believed, by some engineers of considerable prominence, to be attended with very remarkable results.

For example, in 1854, Horatio Allen*, a leading authority in American steam engine practice, reported the witnessing of experiments with an 8x12-inch steam engine, driving four printing presses in New York City, which would run but one printing press when receiving steam at 80 pounds pressure, cut-off at 3 inches of the stroke; whereas, when the engine

*W. H. Shock on "The Cloud Engine," *Journal Franklin Institute* 1854.

The general arrangement of the testing plant is shown in Fig. 1.

To condense the exhaust steam a "Wheeler" surface condenser was employed.

The air supplied to the engine during the tests was taken from a large reservoir, about 30 inches diameter and 12 feet long.

The volume of this reservoir was determined by weighing the water necessary to fill it, which was 3,464.25 pounds at 70° F.

One cubic foot of water at this temperature weighs 62.355 pounds.

The volume of reservoir in cubic feet was therefore

$$3{,}464.25 \div 62.355 = 55.555 \text{ cubic feet.}$$

The volume of one pound of air at 70° F. is 13.342 cubic feet, hence the contents of the reservoir in pounds of air at 70° F. is

$$55.555 \div 13.342 = 4.1609 \text{ pounds per atmosphere.}$$

The reservoir and connections, valves and piping to engine, were tested for leakage by hydraulic pressure to 300 pounds per square inch.

The compressor used was a "Rand Drill Co." compressor situated in the basement of the Institute.

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received air compressed at 20 pounds pressure during the first 1½ inches of the piston travel, and then took steam at 80 pounds pressure up to 3 inches of the stroke, all four of the presses could be driven.

Mr. Allen was so strongly impressed with this performance, that he prophesied the general adoption of such a system as embodyiug a substantial improvement in steam engine practice.

The idea attracted considerable attention for many years, during which the same paradoxical results were occasionally reported, without any explanation of them being offered, other than the opinion that they were due to the application of the air to engines whose action was crippled through a deficient supply of steam, so that the introduction of the air simply rendered such engines capable of the normal performance due to a proper steam distribution.

Later the injection of air into steam boilers of locomotives was urged as affording economy, by allowing the air to pass through coils in the smoke box on its way to the boiler. A trial of this idea was made on an English railway, and it was considered by the Pennsylvania Railroad.

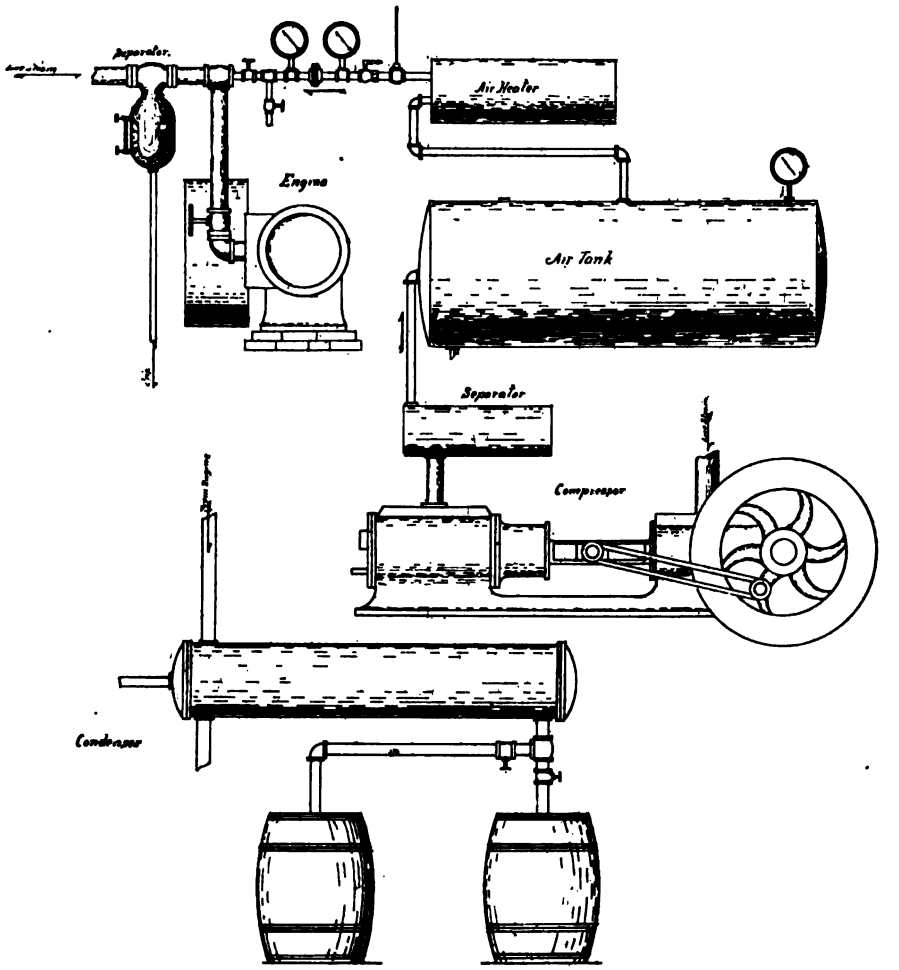

FIG 1.

GENERAL ARRANGEMENT OF APPARATUS.

Two thermometers made by Richards & Co., Ltd., of New York, reading to 100° C., were used to measure the temperature of the air; these were tested with the apparatus for that purpose in the Physical Laboratory of the Institute.

One made by H. J. Green, Brooklyn, reading to 600° F., was used to measure the temperature of the air, when heated, in the last five tests. Three "Ashcroft & Co.," N. Y., gauges registering to 200 pounds were used to register the air and steam pressures. These gauges were tested before and after the tests by the apparatus for that purpose in the Mechanical Laboratory at the Institute.

The indicator was tested to make sure that there was no undue friction and to determine the correct scale of spring, the latter being found to be 59.527 pounds per inch.

METHOD OF CONDUCTING TESTS.

The air from the compressor was run through two separators to eliminate the cooling water, then into the reservoir until the pressure was about 205 pounds. Connections to the compressor were then closed and the reservoir allowed to come to a uniform temperature.

The results, however, were too indefinite to prove any advantage from the use of the air, and competent discussion* showed that any sensible gain was inconsistent with physical principles.

When, however, the indicator and feed-water measurements had exposed the existence of the waste due to the phenomenon of cylinder condensation, the idea arose that perhaps the admixtion of air with steam resulted in a reduction of this waste. This idea received authoritative support in 1872, from a paper in the *Proceedings* of the Royal Society, by Prof. Osborne Reynolds, which detailed experiments showing that the introduction of a comparatively small proportion of air into a glass vessel containing steam, under a partial vacuum, largely retarded the condensation of the steam upon a cold metallic surface located within the vessel.

Eminent modern practical steam authorities,† therefore, have assumed the possibility of an economical influence due to the introduction of air into the steam chest of a steam engine, by virtue of the reduction of the per-

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* Warsop's Aero Engine, London *Engineering*, 1872.

† Geo. H. Babcock on "Substitutes for Steam," *Transactions American Society Mechanical Engineers, Volume VII.*

Before starting the test the drip at the bottom of the reservoir was opened for a moment to remove any condensed water.

The temperature of the air in the reservoir was measured by means of thermometers placed in two mercury wells, the lower ends of which extended a little beyond the center line of the tank.

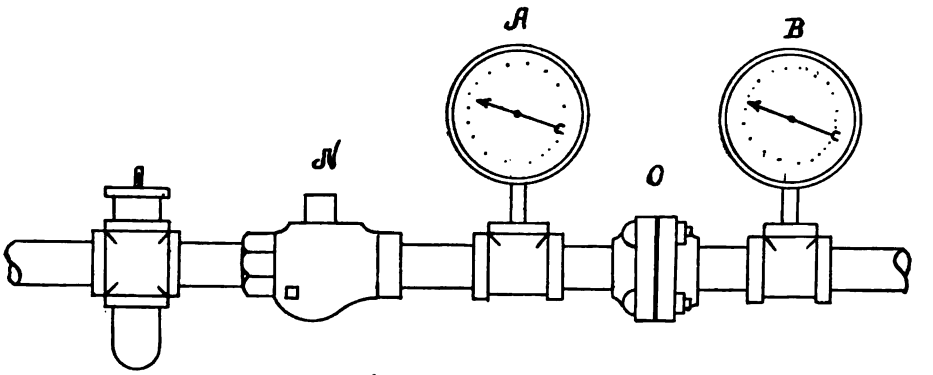

FIG. 2.

APPARATUS FOR REGULATING THE RATE OF FLOW OF THE AIR INTRODUCED INTO THE STEAM MAIN.

The air in going to the engine passed through a needle-valve N, Fig. 2, regulating the air pressure, and then through a small

centage of cylinder condensation, which applies with the use of steam alone.

A somewhat unsatisfactory trial, to test this theory, was made by the Pennsylvania Railroad in 1884, with their shop engine at Altoona, which showed a small loss by use of the air.

So far as I know, however, the idea has never been investigated completely by the exact measurement of all the elements concerned. I therefore suggested the inquiry which Messrs. Leber, Hewitt, and Benedict, have made as a thesis, and under the skillful direction of Professor Jacobus, their investigation has been a thorough one for quantities of air up to 9 per cent. of the steam by weight. The results are conclusive proof that for these proportions of air, the use of it does reduce the cylinder condensation, so that the water per indicated horse-power per hour is about three pounds in 32, less than it is with steam alone, but the power to compress the air more than compensates this gain in economy.

J. E. DENTON

orifice in the plate O, which was one-tenth inch in diameter in some of the tests and one-fifth of an inch in others.

Two gauges A and B registered the pressure on either side of this orifice. The flow of air through the needle valve N was so regulated that the gauge A registered a constant pressure above the gauge B. A constant rate of flow of air into the steam was thus maintained throughout each test. To vary the quantity of air in the different tests the difference of the pressures registered by the gauges A and B was made more or less, and in two of the tests the orifice was made larger than in the others.

In order to secure dry saturated steam for the engine, it was passed through a "Stratton" separator placed close to the engine. The amount of steam was determined by condensing and weighing the exhaust.

During the test, cards were taken at five-minute intervals together with simultaneous readings of revolutions, pressures, and temperatures at engine and reservoir.

After many preliminary tests for practice, four sets were taken, as follows, with the indicated horse-power as nearly constant as possible.

Tests 1 and 1A, using steam alone.

Test 2, 2A, 3, and 4, using, air and steam, the air cold. Temp. of air on entering steam pipe, about 70° F.

Tests 5, 6, and 7, using air and steam, the air heated to about 540° F., or to a temperature about that corresponding to adiabatic compression.

Test 8 and 9 same conditions as the last of the above mentioned tests, except that the air orifice was increased to twice its original diameter.

One indicator card from each of the tests 1, 1A, 2, and 3, is represented in the accompanying figures.

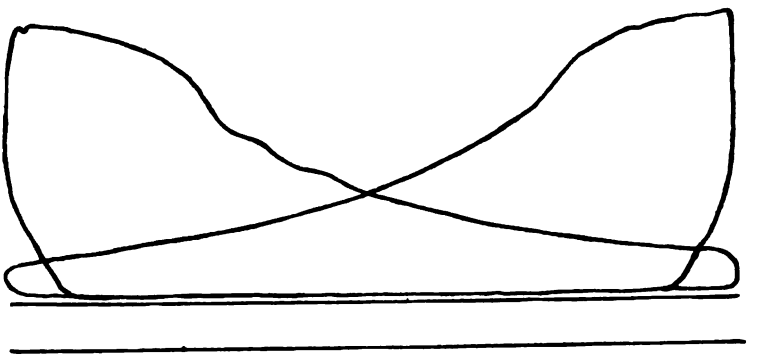

FIG. 3.—TEST NO. 1. CARD NO. 6.
Steam Pressure = 90 lbs. per sq. in. above atm.
Revolutions = 212 per minute.
Average M. E. P. = 38.67 lbs. per sq. in.

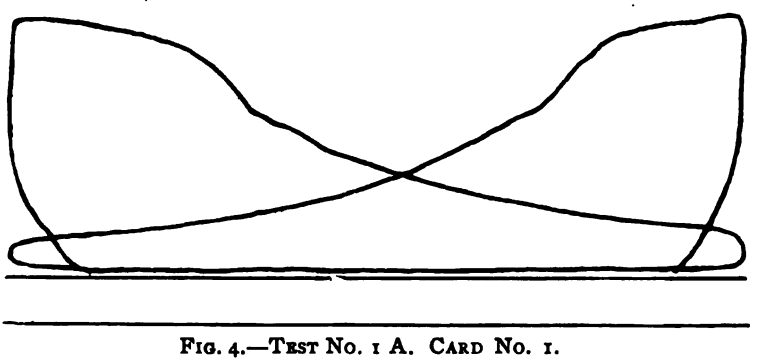

FIG. 4.—TEST NO. 1 A. CARD NO. 1.
Steam Pressure = 90 lbs. per sq. in. above atm.
Revolutions = 228 per minute.
Average M. E. P. = 36 81 lbs. per sq. in.

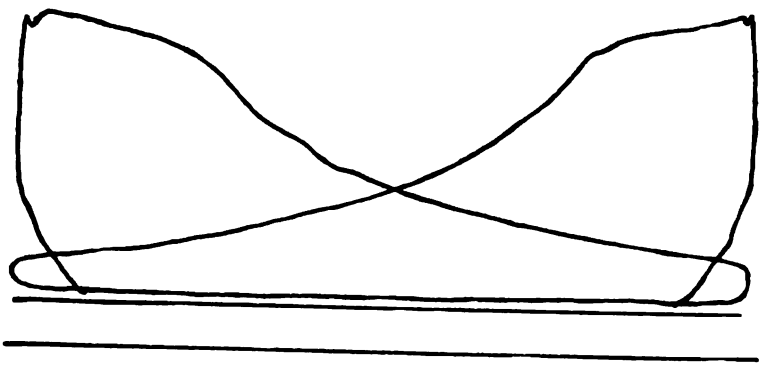

FIG. 5.—TEST NO. 2. CARD NO. 4.
Steam Pressure = 89 lbs. per sq. in. above atm.
Revolutions = 216 per minute.
Average M. E. P. = 36.63 lbs. per sq. in.

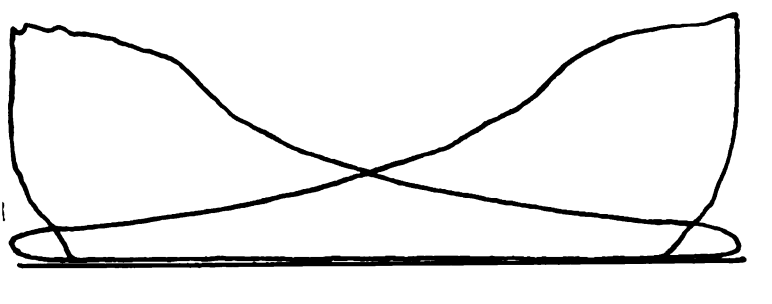

FIG 6.—TEST NO. 3. CARD NO. 3.
Steam Pressure =78 lbs. per sq. in. above atm.
Revolutions = 200 per minute.
Average M. E. P. = 32.57 lbs. per sq. in.

Details of Test No. 1.—Engine Test. No air introduced in steam main.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	40.55	37.61	216	90	....
2	40.44	39.97	188	91	....
3	38.37	39.70	210	85	....
4	38.10	37.17	186	85	....
5	39.50	38.80	204	95	....
6	37.17	39.80	212	90	....
7	35.97	36.68	200	80	353
Average..	38.63		202.3	88	353

Corrected M. E. P. in lbs. per sq. in. is

$(38.63 \div 60)\ 59.527 = 38.323.$

H. P. $2\ P\ L\ a\ n \div 33{,}000$, where P is M. E. P.

a the area of piston;

and n the revolutions per min.

H. P. $= 2\ (38.323 \times 14 \times 39.829 \times 202.3) \div 33{,}000 = 21.831.$

Water per hour is $(353 \div 30)\ 60 = 706$ lbs.

Water per hour per H. P. is $706 \div 21.831 = 32.33$ lbs.

THEORETICAL STEAM FROM CARDS.

Test No. 1.

Steam accounted for at release.

Steam $= 13{,}750 \times R \times d \div$ M. E. P.

Pressure at release in lbs. per sq. in. above atm. 16.568

Density in lbs. per cu. ft..... .07714

M. E. P. in lbs. per sq. in.....38.0817

Ratio of volume of cylinder filled with steam,

$3.2083 \div 3.8$..... .84429

Steam in lbs. per hour per H. P.$= 13{,}750 \times .84429$

$\times .07714 \div 38.0817 = 23.515.$

Water per hour per H. P. in lbs.....32.33

Steam at release, calculated from card.....23.515

Steam not accounted for at release in lbs..... 8.815

$8.815 \div 32.33 = 27.2\%$ not accounted for at release.

Test No. 1A. No Air Introduced in Steam Main.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	40.53	32.70	228	90	. .
2	39.34	34.92	210	85	....
3	38.54	33.87	210	83	....
4	37.70	34.54	222	82.5	....
5	38.99	35.14	210	85	....
6	39.94	35.84	234	87	....
7	38.13	34.83	192	82	362
Average..	38.03		215.14	84.9	362

Corrected M. E. P in lbs. per sq. in..... 37.723

H. P..... 22.849

Water per hour in lbs..... 724.

Water per hour per H. P. in lbs. ..... 31.682 lbs.

Test No. 2.—Air and Steam. Air at 5 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	42.23	40.36	192	88	...
2	40.53	39.10	204	90	....
3	40.57	39.30	216	90	....
4	30.16	38.23	216	89	....
5	41.17	39.56	192	90	....
6	41.70	39.70	194	92	....
7	42.35	42.37	194	89	....
8	40.04	37.83	192	86	....
9	41.96	39.33	198	94	....
10	43.33	39.40	180	93	....
11	40.43	37.61	198	86	565
Average..	41.33		197.8	89.7	565

Corrected M. E. P. in lbs. per sq. in.....	40.005
H. P.....	22.283
Water per hour in lbs.....	678.
Water per hour per H. P. in lbs.....	30.43

To get the total air used in each test, the final and initial reservoir pressures and temperatures were taken and reduced to the corresponding pressures at 70° F., and their difference reduced to atmospheres.

The capacity of the tank in pounds of air at one atmosphere will be its volume in cubic feet divided by the volume of one pound of air at the engine-room temperature, which was taken as 70° F.

The air used is therefore this capacity multiplied by the difference in atmospheres.

WORK DONE IN COMPRESSING THE AIR.

If the compression is adiabatic the work to compress a pound of air is

$$U = 183.5\ (T_2 - T_1)$$

and

$$T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{.29}$$

In which

U is the work in foot-pounds per pound of air.

T_1 = absolute temperature of air before comparison.

T_2 = absolute temperature of air if compressed adiabatically to the average steam pressure.

p_1 = pressure of air before compression = one atmosphere.

p_2 = average absolute pressure of steam.

To obtain the horse-power expended in compressing the air, multiply U by pounds of air per hour and divide by 1,980,000. Subtracting this horse-power from the indicated horse-power of the test, the net or "steam horse-power" is obtained.

Test No. 2 Continued—Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial...	14.2	57.56	200	243.22	....	...
Final	10.	50.	118	158.2	5.7887	28.878

To obtain the horse-power required to compress 28.878 pounds of air per hour we have:

$$p_2 = 89.7 + 14.7 = 104.4 \text{ lbs. per sq. in.}$$

$$\frac{p_2}{p_1} = \frac{104.4}{14.7} = 7.102$$

$$\left(\frac{p_2}{p_1}\right)^{.29} = 1.766 = \frac{T_2}{T_1}$$

$$T_2 = 937.7^\circ \text{ Fahr.}$$

$$T_1 = 70 + 461 = 531^\circ \text{ Fahr.}$$

$$U = 183.5\ (937.7 - 531) = 74629 \text{ ft. lbs.}$$

$$\text{H. P. to compress air} = \frac{74629 \times 28.878}{1980000} = 1.089$$

Ind. H. P.....22.283
Ind. H. P. — air H. P. = steam H. P.....21.194
Water per hour per ind. H. P. in lbs..... ...30.43
" " " steam H. P. in lbs 31.99

In the remainder of the tests the tables will be made out in the same manner, but the results only of the calculations will be given.

Test No. 2A.—Air and Steam. Air at 5 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Minute.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	33.307	41.107	186	85	....
2	36.80	45.97	222	94	....
3	36.066	45.007	192	92	....
4	34.033	40.36	190	84	....
5	35.166	44.077	192	90	....
6	38.70	47.966	204	97	....
7	34.74	42.90	204	88	...
8	35.966	44.57	204	91	..
9	33.933	42.94	180	86	...
10	37.233	46.33	204	96	....
11	33.20	41.50	204	85	577
Average..	40.42		198.36	89.8	577

Corrected M. E. P. in lbs. per sq. in..... ... 40.11

Ind. H. P..... 22.409

Reservoir Readings

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial ...	16.2	61.15	200	228.94	....	...
Final ...	11.8	53.24	113	148.57	5.4621	27.136

H. P. to compress air..... 1.023

Ind. H. P..... 22.409

Steam H. P.... ... . 21.386

RESULTS.

Water per hour in lbs..... ..... 692.4

Water per hour per ind. H. P. in lbs..... 30.89

Water per hour per steam H. P. in lbs..... 32.33

Test No. 3.—Air and Steam. Air at 10 Pounds Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Minute.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	39.02	35.62	206	88	. .
2	34.61	35.46	198	87	....
3	32.48	33.18	200	78	....
4	37.22	38.60	198	98	....
5	39.40	39.67	210	91	....
6	35.16	39.72	180	89	....
7	37.29	39.52	198	90	....
8	40.32	42.80	207	100	....
9	41.44	39.50	200	85	425.5
Average..	37.83		199.6	90.6	425.5

Corrected M. E. P. in lbs. per sq. in..... 37.513

Ind. H. P..... 21.085

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial . . .	16.6	61.88	205	231.9	....	....
Final	12.	52.36	108	141.15	6.1737	38.522

H. P. to compress air..... 1.460

Ind. H. P..... 21.085

Steam H. P..... 19.625

RESULTS.

Water per hour in lbs..... 638.

Water per hour per ind. H. P. in lbs..... 30.27

Water per hour per steam H. P. in lbs..... 32.51

Test No. 4—Air and Steam. Air at 15 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Minute.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.
	Crank.	Head.			
1	40.42	35.59	228	90	....
2	38.07	34.50	206	90	....
3	39.03	34.83	210	89	....
4	38.43	34.78	210	87	....
5	36.40	32.92	216	85	....
6	37.27	34.43	212	87	....
7	35.43	31.80	204	82	301
Average..	35.52		212.3	87.1	310

Corrected M. E. P. in lbs. per sq. in..... 35.241

Ind. H. P..... .... 21.068

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial....	15	59.	200	237.28	....	....
Final	18	59.4	113	142.78	6.4285	53.496

H. P. to compress air..... 1.982

Ind. H. P..... 21.068

Steam H. P..... 19.086

RESULTS

Water per hour in lbs..... 620.

Water per hour per ind. H. P. in lbs..... 29.42

Water per hour per steam H. P. in lbs..... 32.49

In the tests just considered the air was run in cold from the tank and had to be heated up by the steam after entering the steam main.

In all of the following tests the pipes through which the air passed to the engine were heated by means of "Bunsen" burners, to a temperature such that the air reached the steam at a temperature corresponding to about that of adiabatic compression, as might be the case if an air-compressing cylinder were on the same bed plate with the steam cylinder.

Test No. 5.—Air and Steam. Heated Air at 5 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Minute.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.	Air Temp. at Engine in Degs. Fahr.
	Crank.	Head.				
1	36.72	43.74	204	92	....	....
2	37.50	43.26	186	92	....	...
3	34.08	39.24	190	84	.. .	....
4	28.86	33.36	186	83	....	....
5	37.02	42.66	201	91	....	....
6	36.90	41.82	195	90	....	....
7	24.54	28.86	180	64	....	....
8	27.42	30.60	188	70	....	....
9	30.66	33.96	186	75	....	....
10	28.44	33.00	190	78	....	....
11	27.12	34.38	180	75	. ..	. ..
12	30.90	35.58	188	78	....	....
13	33.12	37.62	198	80	582	...
Average..	34.28		190.1	80.54	582	534.7

Corrected M. E. P. in lbs. per sq. in 33.954

Ind. H. P..... 18.177

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial....	22.4	72.32	192	185.84	....	....
Final	17.4	63.32	141	155.87	2.038	8.4899

H. P. to compress air..... .300

Ind. H. P..... 18.177

Steam H. P..... 17.877

RESULTS.

Water per hour in lbs..... 582.

Water per hour per ind. H. P. in lbs..... 32.029

Water per hour per steam H. P. in lbs..... 32.56

Test No. 6.—Air and Steam. Heated Air at 10 Pounds Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Minute.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.	Air Temp. at Engine in Degs. Fahr.
	Crank.	Head.				
1	29.46	35.74	192	81	....	....
2	31.68	38.85	200	88	..	....
3	29.85	37.95	188	82	....	....
4	33.90	40.80	194	87	....	....
5	33.81	39.21	198	86	....	....
6	33.66	38.85	192	85	....	....
7	34.56	39.36	192	85	....	....
8	31.36	36.66	192	82	....	...
9	33.60	37.50	198	88	...	....
10	34.64	40.71	194	89	...	....
11	33.15	38.65	194	84	486	...
Average..	35.586		194	85.18	486	475.3

Corrected M. E. P. in lbs. per sq. in..... 35.3048

Ind. H. P..... 19.287

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial....	29.	84.2	187	182.12	....	....
Final	24.2	75.3	117	115.84	4.508	22.508

H. P. to compress air..... .823
Ind. H. P..... 19.287
Steam H. P..... 18.464

RESULTS.

Water per hour in lbs.... ..... 595.2
Water per hour per ind. H. P. in lbs..... 30.234
Water per hour per steam H. P. in lbs..... ... 32.24

Test No. 7.—Air and Steam. Heated Air at 15 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. Above Atm.	Water in Lbs. from Condenser.	Air Temp. at Engine in Degs. Fahr.
	Crank.	Head.				
1	37.68	43.02	192	95	....	....
2	33.30	40.14	184	87	. ..	...
3	29.94	34.86	183	75	....	....
4	30.72	35.88	190	78	....	...
5	32.76	37.32	186	81	....	...
6	29.40	33.84	180	74	....	....
7	30.42	34.62	180	75	....	....
8	35.16	40.74	192	85	...	....
9	34.08	38.64	204	85	382	....
Average..	35.14		187.9	81.7	382	574.1

Corrected M. E. P. in lbs. per sq. in..... 34.862
Ind. H. P..... 18.447

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F.°	Gauge.	At 70°		
Initial....	22.	71.6	195	190.64	....	....
Final	15.5	59.9	126	147.24	2.952	18.4248

H. P. to compress air..... .057
Ind. H. P..... 18.447
Steam H. P..... 17.790

RESULTS.

Water per hour in lbs..... 573
Water per hour per ind. H. P. in lbs..... 31.09
Water per hour per steam H. P. in lbs..... 32.21

In the next two tests the orifice was enlarged to twice its original diameter to secure tests with heated air with as large a ratio of air to indicated horse-power as prevailed in the tests with cold air.

Test No. 8.—Air and Steam. Air Heated.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. above Atm.	Water in Lbs. from Condenser.	Air Temp. at Engine in Degs. Fahr.
	Crank.	Head.				
1	34.05	41.10	196	89	....	....
2	31.86	39.42	186	83	....	....
3	32.25	40.71	192	87	...	....
4	32.46	40.41	194	86	....	....
5	31.80	39.06	198	85	...	....
6	31.56	39.21	192	83	....	....
7	32.40	40.65	194	86	....	....
8	32.70	39.96	204	84	....	....
9	34.10	42.21	194	89	401.5	....
Average..	36.44		194.44	85.8	401.5	571.6

Corrected M. E. P. in lbs. per sq. in..... 36.152
Ind. H. P..... 19.794

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atms.	Lbs. of Air per Hour.
	C°	F.°	Gauge.	At 70°		
Initial....	23.3	73.94	193	191.57	....	....
Final.....	19.2	66.56	122	122.72	4.683	29.228

H. P. to compress air..... 1.073
Ind. H. P..... 19.794
Steam H. P..... 18.721

RESULTS.

Water per hour in lbs..... 602.25
Water per hour per ind. H. P. in lbs..... 30.426
Water per hour per steam H. P. in lbs..... 32.17

Test No. 9.—Air and Steam. Heated Air at 20 Lbs. Difference of Pressure on Two Sides of Orifice.

Card.	M. E. P. of Cards.		Revolutions per Min.	Steam Pressure in Lbs. per Sq. In. above Atm.	Water in Lbs. from Condenser	Air Temp. at Engine in Degs. Fahr.
	Crank.	Head.				
1	32.22	37.05	196	80	....	...
2	28.75	34.80	195	75	....	....
3	32.10	39.45	201	90	....	....
4	34.50	40.35	198	90	...	...
5	30.00	36.45	192	84	....	....
6	30.78	38.25	198	90	....	...
7	34.86	39.66	201	87	....	....
8	32.16	38.25	192	85	357	....
Average..	34.977		196.62	85.1	357	527.25

Corrected M. E. P. in lbs. per sq. in..... 34.7006
Ind. H. P..... 19.212

Reservoir Readings.

	Temp. of Air.		Air Pressure.		Diff. in Atm's.	Lbs. of Air per Hour.
	C.°	F°	Gauge.	At 70°		
Initial....	26.2	79.16	200	196.61	....	....
Final ...	20.	68.	134	134.40	4.232	30.1867

H. P. to compress air..... .... 1.104

Ind. H. P..... ..... 19.212

Steam H. P..... ... 18.108

RESULTS

Water per hour in lbs..... 612.

Water per hour per ind. H. P. in lbs..... 31.85

Water per hour per steam H. P. in lbs..... 33.80

Tabulated Results of Tests.

Test No.	Ind. H. P.	Air per Hour in Lbs.	Air per Hour per H. P. in Lbs.	Av'ge Air Temp. at Engine in deg. Fahr	H. P. to Compress the Air.	Ind. H. P. less H. P. to Compress the Air.
	1	2	3	4	5	6
1	21.831	...	....	....	....	....
1A	22.849	....	...	....	....	...
2	22.283	28.878	1.2959	68.8	1.890	21.194
2A	22.409	27.136	1.2109	73.2	1.023	21.386
3	21.085	38.532	1.827	73.1	1.460	19.625
4	21.068	53.496	2.539	74.7	1.982	19.086
5	18.177	8.4899	.467	534.7	.300	17.877
6	19.287	22.508	1.167	475.3	.823	18.464
7	18.447	18.424	.998	574.1	.657	17.790
8	19.794	29.228	1.476	571.6	1.073	18.721
9	19.212	30.186	1.571	527.2	1.104	18.108

	Water per Hour per Ind. H. P. in Lbs.	Water per Hour H. P. given in Col. 6 in Lbs.
1	32.33	....
1A	31.68	....
2	30.43	31.99
2A	30.89	32.33
3	30.27	32.51
4	29.42	32.49
5	32.029	32.56
6	30.234	32.24
7	31.09	32.21
8	30.426	32.17
9	31.85	33.80

SUMMARY.

From the tabulated results the following conclusions may be drawn:

By the introduction of the compressed air, the water per hour per indicated H. P. is perceptibly reduced, in our case between one and two pounds in about 32 pounds, or about 7 per cent.

When, however, the theoretical work done in compressing the air is allowed for, the economy is about the same as when using steam alone, and it would be still further reduced by the frictional wastes of the air compressing mechanism.

PORTLAND CEMENT REFERENCES. 1892-96.

BY PROF. THOS. B. STILLMAN, PH. D.

(Continued from Vol. 10, 1893.)

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Zeitschrift für Angewandte Chemie.—Zur Bestimmung des spec. Gewichtes von Cement u. dgl. festen Stoffen bringen, L. Erdmenger und Ch. Mann, 25 order 50 grms. der Probe in ein 50cc. Kölbchen und lassen aus einer mit einem Wasserkühlmantel versehenen Bürette, Wasser oder Terpentinöl bis zur Marke zufliessen, p. 26. Die Werthbestimmung von Mergeln für hydraulische Zwecke durch chemische Analyse (G. Lunge und M. Schochor—Tscherny), p. 481. Der Portlandcementfabrik von Dyckerhoff & Söhne, pp. 414,415.

(TO BE CONTINUED.)

OBITUARY.

ERNEST S. CRONISE.

Ernest S. Cronise died at Ridgewood, N. J., September 14, 1896.

He became ill with malarial fever in February last, and thinking a change of climate would benefit him, went South, March 1, to inspect the Georgia Central Railway system.

After an absence of six weeks he returned to New York but little improved, continuing at his post, however, until the latter part of May, when he became very much worse.

With a change for the better after some weeks at Ridgewood, N. J., it was hoped that complete recovery would follow, but the intense heat in August affected his condition very seriously, and he declined rapidly thereafter until the day of his death.

Ernest S. Cronise was born in New York, October 16, 1861. He prepared for Harvard at Hunt's Collegiate Training School in New York, but during his last year developed such a decided taste for mathematical studies that he was advised by a well-known railroad man to take up engineering. At the yearly examination, at this school, he received the gold medal for superior excellence in mathematics and languages.

He entered the Stevens Institute in October, 1878, and graduated in June, 1881.

The following spring he entered the employ of the Pennsylvania R. R. as apprentice in the Fort Wayne Shops. Later he was with the N. Y., W. S. & Buffalo R. R., on expert work for the motive power department. He also held the position of Superintendent of Car Construction for this road at the Pullman Shops. In 1885 he entered the shops of Henry R. Worthington, in Brooklyn, N. Y., and at the end of a year was engaged in superintending the erection of various Worthington pumping engines for waterworks. Among these may be mentioned two vertical engines for the Cincinnati Water-Works, of 25,000,000 gallons capacity, which was a work of considerable engineering importance, being the first vertical direct-acting pumping engine of any size ever constructed. Later he was Confidential Secretary in New York and Superintendent of branch offices and agencies.

In September, 1894, he established himself at 37 Broad Street, New York City, as a Consulting Engineer, where he has made an enviable reputation as a railway expert, his contributions to the *Bond Record* having received favorable comment from leading American and English financial papers. His reports on the Baltimore and Ohio R. R., and on the Erie Railway Co., which ap-

peared in the *Bond Record*, were esteemed by prominent financiers remarkable for their scope and clearness. One of the leading investment houses said: "He possessed a rare combination of qualities which peculiarly fitted him to be a trusted adviser upon railway investments; that, first of all, being incorruptible, his reports could be trusted absolutely, and added to these, he possessed a high all-round ability as an engineer, with an excellent business judgment. He was quick to see the good and weak points of a property, and singularly sagacious as to what should be done to improve it. He was possessed of a combination of qualities as unusual as admirable. His business associates have met a serious loss; one which at the moment I do not see how it can be well supplied. I cannot better express my feelings than to quote what Robert Lewis Stevenson says of a friend of his, 'He died too early, at the very moment when he was beginning to put forth fresh sprouts and blossom into something worthy of himself, and yet none who knew him will think he lived in vain. He was, indeed, a good influence in life.'

He was a member of the American Society of Mechanical Engineers, Engineers' Club, and New York Railroad Club.

HERBERT B. COOK.

The death of Herbert B. Cook occurred by drowning on August 23, 1896.

While bathing in the surf at Atlantic City with a party of friends, a large breaker is said to have swept the bathers into deep water, and in struggling to save a young girl, who was one of his party, it is believed that Mr. Cook was taken with heart failure.

The sudden disappearance of his body, he being a good swimmer, and the water being shallow where the body went down, would indicate that the drowning was due to this cause.

Mr. Cook was born November 5, 1870, at Middletown, Conn. He received his preparatory education at the Brooklyn Polytechnic School and the Woodbridge School in New York City. Entering the Stevens Institute in 1890, he graduated with the Class '93, which he had joined in the second term of its freshman year.

After graduation from the Institute he was employed for about one year in the machine shops of the Pencoyd Iron Works.

He then accepted the position of Assistant Engineer with C. H. Gifford & Co., agents for the B. F. Sturtevant Co., in Philadelphia, and later, after the death of Mr. Andrew Shiebler, Stevens '92, who had been his superior, was promoted in August, 1895, to the position of Chief Engineer, in which capacity he did excellent work until the time of his death.

He was a careful student, and a worker, and was rapidly acquiring a thorough knowledge of the most advanced ideas and practice in heating, ventilating, forced draft, etc., when his successful and useful career was so suddenly ended.

"STEVENS LIFE"—PROSPECTUS.

With the college year '96-'97 *Life* enters upon the sixth year of its existence as the literary representative of Stevens Institute among the colleges. The policy of the Board for '96-'97 is aggressive. No efforts will be spared to make the paper as attractive and interesting to its subscribers as possible- A movement is on foot to make the paper more technical in character than formerly, giving it a certain distinction from the ordinary college paper that a representative of our unique institution should have. Several of the faculty have already promised short articles on subjects of interest to mechanical engineers (*in embryo*), and any such favors from any of our alumni who can spare the time will be highly appreciated by the Board and the college in general. Not that we wish to conflict with the INDICATOR in any way, but we hold that subjects, not too severely technical, will prove highly interesting to the undergraduate body and not at all out of place in the columns of *The Stevens Life*. Otherwise, the paper will contain its usual round of reports of games, concerts, meetings, etc., and we expect them fully up to the mark. Our literary department will be somewhat of an experiment this year, for while we encourage literary efforts among the undergraduates, nay, beg them to send us the best they can produce, we do not intend to publish any story that is not fully up to the standard set by the literary magazines of the different colleges around us. We hope to see more of the alumni giving us their subscriptions, as *Life* is never more than just able to pay its expenses, and the whole work, from business managership down, is purely disinterested.

The interest in college affairs it arouses and the old memories it awakens ought well to repay the money invested, and, it is to be remembered, that *Life*, going as it does into upwards of 75 of the most prominent colleges in the land, contributes its little towards making the fair name of our famous Institute brighter.

On these lines we hope to see *Life* become a more and more worthy product of Stevens Institute, and thus we give greeting for '96, hoping that it may prove a welcome visitor to many of our alumni who like to dwell upon those four years now long gone by.

INSTITUTE NOTES.

THE 25TH ANNIVERSARY OF THE STEVENS INSTITUTE OF TECHNOLOGY.—The Executive Committee of the Alumni Association presented in its report to the annual meeting in June, a program for the celebration of the 25th anniversary of the Institute, and also suggested the names of alumni to constitute a committee which should have charge of the arrangements of the proposed celebration, in conjunction with a committee representing the Trustees, and another committee representing the Undergraduates.

The Association failed, however, to take action upon this report, and the Executive Committee, therefore, at a special meeting called for the purpose, on September 22, 1896, appointed the following anniversay committee:

Robert M Dixon, '81, Chairman; A. R. Wolff; '76, J. W. Lieb, Jr., '80; Joseph Wetzler, '82; Wm. H. Bristol, '84; J. H. Cuntz, '87; and E. P. Roberts, '77, President of the Alumni Association, member ex-officio

The committee of the Board of Trustees consists of Alexander C. Humphreys, Chairman, F. E. Idell. and President Morton.

The Undergraduates are represented by Walter Kidde, '98, A. B. Macbeth, '97, E Grelle, '98, and Geo. H. Beck, '99.

The joint committee met for the first time, Friday, October, 9, 1896, at the residence of President Morton. The following members were present.

President Morton, Alexander C. Humphreys, A. R. Wolff, John W. Lieb, Jr., Joseph Wetzler, J. H. Cuntz, Walter Kidde, and A. B. Macbeth.

President Morton was chosen Chairman, Walter Kidde, Secretary; and Robert M. Dixon, Treasurer.

For several reasons, among which were given the proximity of the national election to the time originally suggested for the celebration, and the little time intervening to complete arrangements, it was deemed advisable to postpone the celebration until the latter part of January or the beginning of February, about the time of the midwinter meeting of the Alumni Association, so that this meeting might be merged with the proceedings of the anniversary.

The date of the celebration was not definitely fixed, but will probably be determined upon at the next meeting of the joint committee.

Various features of the program to be arranged were discussed and decided upon. In place of the smoker previously proposed it was concluded to have a promenade concert, to be preceded by a short meeting of the Alumni Association.

The program will make provision for informal class dinners to be arranged for at times not taken up by other events.

It was also decided to request each graduate to contribute $2.00 towards defraying the expenses to be incurred, which amount will cover the cost of the souvenir publication to be issued.

The athletic games provided for in the program first proposed having to be omitted in consequence of the later date selected for the celebration, the undergraduate members of the committee were requested to report some feature of the entertainment as a substitute for these games.

The alumni will be informed, by circular-letter, of the date of the celebration as soon as the same is fixed.

PROFESSOR LEEDS, at the request of Commissioner Willis of the Department of City Works of Brooklyn, N. Y., recently investigated and reported upon the condition of the water supply of that city and suggested a method for its improvement.

A JOINT committee of the Tariff Association of New York, the Architectural League of New York, and the American Society of Mechanical Engineers was appointed some time ago to investigate and test fireproofing for structural metal in buildings and to obtain data for standard specifications.

Mr. H. de B. Parsons, '84, is a member of this committee, representing the American Society of Mechanical Engineers.

The committee is assisted by an Advisory Board, of which President Morton is a member.

The first set of tests of the series to be conducted were compression tests of steel and cast iron columns without any fireproofing, which are to serve as a basis of comparison for subsequent tests.

A report upon these tests has already been published.

The Uehling & Steinbart pyrometer is used by the committee for the measurement of the high temperatures, to which the material to be tested will be submitted.

PROFESSOR JACOBUS CONTRIBUTED, by correspondence, a discussion of the paper on "The Thermal Efficiency of Engines," by Henry Riall Sankey, Capt. R. E., which was presented last year to the Institution of Civil Engineers, London.

THE FOLLOWING PAPERS were presented at the meeting of the American Association for the Advancement of Science, held at Buffalo, last August:

By Professor Denton. "New Water Prony Brake for Testing Steam Turbines Without Reduction Gearing."

By Professor Jacobus. "Apparatus for Tracing a Curve Representing the Force Required to Overcome the Inertia of the Reciprocating Parts of a Steam Engine."

"An Apparatus for Accurately Measuring Pressures of 2,000 Pounds per Square Inch and Over."

"Apparatus for Observing the Distribution of Moi sture in a Steam Main."

"Values of Heat Combustion of Various Gases per Cubic Foot for Use in Calculating the Heating Power from the Analysis of a Gas."

THE INSTITUTE LIBRARY has been designated by Hon. George B. Fielder to receive the publications of the United States Geological Survey for 1894 and subsequent years to date.

Some of these publications have already been received and more will be sent as they become available.

"I AM TOLD THAT 'STEVENS' has graduated a larger class than usual this year, and I am pleased to say that she has reason to be proud of her success, judging from the characteristics of these gentlemen whom I have been privileged to meet."

The above is an extract from a letter received at the Institute from the secretary af a firm which has three of the Institute's graduates in its employ.

The occasion for writing the above was an application for a graduate to fill another position with this firm.

AT THE SPECIAL MEETING of the Executive Committee of the Alumni Association, held at the Institute September 22, 1896, there were present Robert M. Dixon, A. Riesenberger, K. Torrance, William H. Bristol, F. D. Furman, and J. Day Flack. The appointment of a committee to act with committees representing the Board of Trustees of the Institute and the undergraduates, which joint committee will have full power to make all arrangements for the 25th anniversary celebration of the Institute, was the only business transacted. President E. P. Roberts, in a letter to the Corresponding Secretary, suggested the names of several alumni for this committee, and Mr. H. de B. Parsons, whose name had been suggested by the Executive Committee of last year requested that he be excused from serving on the committee on account of the numerous other committee duties which he had already accepted.

A GREAT ENGINEER HONORED,—Commodore George W. Melville, Engineer-in-Chief of the United States Navy, has received the degree of Doctor of Engineering from Stevens Institute. But once before in the history of Stevens Institute has this degree been conferred, Prof. R. H. Thurston, Director of Sibley College, Cornell University, having been the recipient of the honor some years ago. During Commodore Melville's administration of the Naval Bureau of Steam Engineering, he has directed the design of all of the machinery of the new navy, the success of which has placed the United States easily ahead of the rest of the world in marine engineering.—*American Electrician*, July, 1896.

The Institute has thus far conferred the honorary degree of Doctor of Engineering upon Mr. E. D. Leavitt, Cambridgeport, Mass., in 1884; Prof. R. H. Thurston, Sibley College, Cornell University, in 1885; Mr. Coleman Sellers, Philadelphia, Pa., in 1888; Mr. Francis B. Stevens, Hoboken, N J., in 1890; Commodore Geo. W. Melville, U. S. N., 1896.

THERE ARE 254 students in attendance at the Institute this year.

The membership of the several classes is as follows: Freshman Class, 68; Sophomore Class, 59; Junior Class, 64; Senior Class, 63.

Five students joined the Junior Class this year from other institutions: T. S. Takeo, from the University of Tokio; Hubert Lang, from the University of Zurich; H. L. McGee, from the Sheffield Scientific School; A. G. van Leenhoff, from the Technical School at Amsterdam, Holland, and A. G. Day, formerly a student of the U. S. Naval Academy, Annapolis

Following is a list of the members of the class of 1900 and their addresses:

H. W. Appleton, Jr., 116 E. 81st St., New York City.
E. S. Baker, Chadds Ford, Pa.
E. S. Barlow, 405 Clermont Ave., Brooklyn, N. Y.
R. A. Benavides, 536 Hudson St., Hoboken, N. J.
Harold Betts, Wilton, Fairfield Co., Conn.
C. K. Brackett, 74 W. 31st St., Bayonne. N. J.
R. S. Bradley, 161 Lincoln Ave., Newark, N. J.
R. D. Brooks, 1131 Bergen St., Brooklyn, N. Y.
H. A. Brown, Jr., Ridgewood, N. J.
R. S. Carter, 130 E. 24th St., New York City.
W. H. Chadwell, Morristown, N. J.
J. W. Clarke, 120 Mercer St., Jersey City. N. J.
Jas. E. Cosgrove, 64 Rush St., Brooklyn, N. Y.
F. Wm. Cox, 45 East Ave., Bridgeton, N. J,
Morgan Cowperthwaite, Yonkers, N. Y.
Lyon de Camp, 35 Mt Morris Ave., New York City.
John H. Drake, 312 W. Church St., Elmira, N. Y.
C. N. Durrie, 60 Glenwood Ave., Jersey City, N. J.
E. G. Eberhardt, 84 Elm St., Newark, N. J.
John Ferguson, 1207 Park Ave., Hoboken, N. J.
M. K. Fitch, 60 High St., Passaic, N. J.
L. S. Greenbaum, 151 E. 71st St., New York City.
Donald Gregory, 257 W. 45th St., New York City.
Chas. Gunther, 349 Halsey St., Brooklyn, N. Y.
H. G. Harrington, 39 Pacific St., Newark, N. J.
H. S. Hayward, 14 Park Pl., Newark, N. J.
H. R. Hyatt, 58 9th St., Hoboken, N. J.
C. R. Jenkins, 205 West Boulevard, New York City.
Wm. Jennings, Jr., Eagle Pass, Tex.
Geo. E. Kirsten, 1013 Garden St., Hoboken, N. J.
G. H. Kuper, 435 W. 21st St., New York City.
Frank F. Lyon, 143 Hewes St., Brooklyn, N. Y.
W. J. Moore, 326 Stuyvesant Ave., Brooklyn, N. Y.
C. T. Myers, 840 N. Broad St., Elizabeth, N. J.
Louis A. Martin, 824 Bloomfield St., Hoboken, N. J.

C. E. Meding, Jr., Paterson, N. J.
Howard V. Meeks, Weehawken P. O., N. J.
L. L. Merriam, Lyons Falls, N. Y
Robt. Moffit, 765 Herkimer St., Brooklyn, N. Y.
L. H. Newman, Hackensack, N. J.
John C. Percy, Chatham, N. Y.
Louis Phillips, Passaic, N. J.
J. R. Peirce, 54 So. Mountain Ave., Montclair, N. J.
Wm. B. Prince, 115 Montague St., Brooklyn, N. Y.
Louis Prival, 220 E. 33d St., New York City.
Henry J. Raphel, 486 Centre St., Orange, N. J.
H. A. Richtberg, 205 W. 41st St., New York City.
William Rouse, 1207 Park Ave., New York City.
R. H. Sander, 24 Ogden Ave., Jersey City Heights, N. J.
Joseph Schaeffler, 315 W. 31st St., New York City.
J. C. Shaw, Jr., 226 Henry St., Brooklyn, N. Y.
Marvin Shiebler, 278 Berkely Pl., Brooklyn, N. Y.
W. J. Sissons, 521 Garden St., Hoboken, N. J.
Geo. C. Stanford, 61 Sayre St., Elizabeth, N. J.
Moses Stein, 460 1st St., Hoboken, N. J.
Thomas C. Stephens, 142 W. 65th St., New York City.
F. R Stevens, Walden, Orange Co., N. Y.
Harry Taylor, 220 Highland Ave., Orange, N. J.
C. R. Underhill, 107 Harrison Ave., Montclair, N. J.
Henry L. Underhill, Croton-on-Hudson, N. Y.
Edward VanWinkle, 205 Tonnelle Ave., Jersey City Heights, N. J.
Frank D. Voorhees, 57 Duncan Ave., Jersey City, N. J.
Murray Weissblatt, 307 Lenox Ave., New York City.
Edward R. Welles, 480 Greene Ave., Brooklyn, N. Y.
J. R. Wemlinger, 214 9th Ave., New York City.
W. C. Willard, 63 Tenafly Road, Englewood, N. J.
Harold E. Williams, 574 High St., Newark, N. J.
A. F. T. Wolff, 514 Hudson St., Hoboken, N. J.

With the exception of the Senior Class, the several classes have met and perfected their organizations for the year 1896-97. At a meeting of '98, held September 28, the following officers were elected:

President, F. D. Kennedy.
Vice-President, R. T. Ode.
Secretary, E. B. Smith.
Treasurer, R. C. Handloser.

Since the meeting, President Kennedy has appointed the following members on the Junior Ball Committee:

H. R. Davis, E. Frank, Jr., E. C. Grelle, and R. C. Post.

It is the intention, if possible, to hold the ball in the spring before Lent, hoping by this means to obtain the presence of more Seniors than have generally attended.

The Sophomore and Freshman Classes have organized with the following officers:

SOPHOMORE CLASS.

President, S. C. Peck. Vice-President, R. P. Jennings.
Secretary, H. G. Taylor. Treasurer, H. Humphreys.

FRESHMAN CLASS.

President, D. Gregory. Vice-President, Wm. Jennings, Jr.
Secretary, F. D. Voorhees. Treasurer, H. S. Hayward.

INSTITUTE PERSONALS.

'75.

U. S. LETTERS PATENT were granted on August 11, 1896, to ISAAC N. KNAPP, who is with the Omaha Gas Company, for improvements in apparatus for treating illuminating gas.

The principal object of his invention is to remove or extract tar, entrained matter, and vapors such as condense at ordinary temperatures in the manufacture of illuminating gases.

'76.

AN ABSTRACT OF WM. KENT'S PAPER on "Some Preventable Wastes of Heat in the Generation and Use of Steam," which appeared in the *Franklin Institute Journal*, December, 1895, is published in Vol. CXXIV. of the Proceedings of the Institution ot Civil Engineers, London, England.

Mr. Kent, in the July issue of the *Digest of Physical Tests and Laboratory Practice*, comments upon the relative value of the product of the strength and elongation of iron and steel, as compared with the strength and elongation taken separately, as a criterion of the quality of these metals.

During the past summer Mr. Kent has been engaged, for the Babcock & Wilcox Company, making tests at Aurora, Ill., of a variety of Western coals with Western furnaces in order to determine the kind of furnace best adapted for burning different varieties of coal.

On August 14, Mr. Kent delivered the commencement address at the Michigan State Agricultural College, Lansing, Mich.

'78.

JOHN F. KELLY, Chief Electrician of the Stanley Electric Lighting Company, Pittsfield, Mass., presented a paper entitled "Some Account of the Evolution of the Inductor Alternator" at the meeting of the Nat. El. L. Assoc., held in New York City, May 5 to 7, 1896.

The paper is published in the *Electrical Engineer*, May 20, 1896.

BROWN AYRES, Dean of Tulane University, New Orleans, La., has charge of the Department of Electrical Engineering at that institution. The equipment of the department includes about twenty dynamos and a large collection of arc lamps, converters, and measuring instruments.

A. A. DE BONNEVILLE is a Solicitor of Patents, Mechanical Engineer, and Attorney-at-Law, and is located at 36 Dey St., New York City.

EDWARD P. THOMPSON'S BOOK on "Roentgen Rays and Phenomena of the Anode and Cathode," published by D. Van Nostrand Co., was issued in August. It is 8vo. size, and contains 50 diagrams and 30 half-tones. Price, $1.50.

'80.

JOHN W. LIEB, JR., has been advanced from the position of Assistant General Manager to General Manager of the Edison Electric Illuminating Company, of New York City.

'84.

W. S. ALDRICH presented a paper entitled "National Endowment of Engineering Research" at the Buffalo meeting of the A. A. A. S., August 25, 1896.

A. J. WURTS conducted a series of tests to determine the feasibility of constructing a simple form of lightning arrester for high potential circuits.

An account of these tests appeared in the *Electrical Engineer* June 10, 1896.

THE SAME ISSUE of this journal describes the so-called junction boxes used by the Edison Illuminating Company, of New York, for switching underground circuits together or apart by switches located at the stations. The mechanism in these boxes is the invention of JOHN VAN VLECK.

C. W. WHITING is in the employ of Messrs. Fraser & Chalmers, Chicago, Ill.

'85.

The *Electrical Engineer* of June 3, 1896, describes the engine exhibit of BURHORN & GRANGER at the exhibition of the N. E. L. Assoc. and makes a very favorable comment upon the completeness and excellence of the engines exhibited by this firm.

HARVEY D. WILLIAMS gives, in the *Sibley Journal of Engineering* for March, 1896, a new method of governing water-wheels.

THOS. G. SMITH, JR., in an article published in the *Electrical Engineer* August 19, 1896, describes the street lighting plant of the village of Norwood, O., in which the direct constant potential current has been applied to the operation of arc lamps.

ROLLIN NORRIS has been granted a patent for improvements in methods and means of carbureting water gas and assigned all rights involved to the United Gas Improvement Company.

A description of the patent is published in the *Amer. Gas Light Jour.* July 27, 1896. The claims of the patentee are:

1. The improvement in the art of carbureting or enriching water gas with oil, which consists in generating blast gas and internally heating fixing chambers by its secondary combustion, then generating water gas and subdividing it, passing one of the subdivisions in contact with oil or liquid hydrocarbon to lick up the more volatile vapors thereof, passing the other of these subdivisions through said previously heated chambers and introducing the less volatile components of the oil or liquid hydrocarbon into it near its point of generation, and reuniting the said subdivisions

comparatively far from the point of generation of the water gas and permitting them to travel together portions of the said chambers comparatively remote from the point of generation of the water gas substantially as described.

2. In combination, a generator, an oil vaporizer, refractory material contained in a fixing chamber having provisions for heating it by direct internal combustion of waste gas, and the described valved pipe connections and their branches for passing a part of the water gas through the vaporizer to lick up the lighter components of the oil, and hence through portions of the checkerwork, and for passing the rest of the water gas and the heavy components of the oil through all the checkerwork, substantially as described.

'86.

CHAS. RUSSELL COLLINS is General Manager of the Seattle, Wash., Gas and Electric Light Company. He was elected an active member of the Pacific Coast Gas Association at the meeting of the Association held at San Francisco, Cal., July 21 and 22, 1896.

E. F. WHITE is located at 136 Liberty St., New York City, and makes a specialty of the designing and operation of manufacturing works.

"THE INDUSTRIAL DEVELOPMENT OF ELECTRIC LIGHTING" is the title of an article contributed by GEO. R. METCALFE to *Electricity* May 20, 1896.

THE TRANSFORMERS exhibited by the Wagner Electric Manufacturing Company, of St. Louis, Mo., at the Electrical Exposition in the Grand Central Palace in New York City, last May, were designed by H. A. WAGNER, the Manager of the company.

W. R. KING has been granted several patents for an electric smelting furnace, and also a patent upon a process for forming calcium carbide.

C. J. FIELD delivered a lecture in the early part of the year at Sibley College, Ithaca, N. Y., on the subject of "The Economical Generation of Power in Central Stations."

EDWARD D. SELF has accepted a position as consulting engineer for a large mining company at Johannesburg, South Africa. His address is Box 550, Johannesburg, South Africa.

'87.

W. EVERETT PARSONS, who was formerly in the employ of the De La Vergne Refrigerating Machine Co., became Manager, last May, of the Newark Hygeia Ice Co., 303-317 Ogden St., Newark, N. J.

'90.

EVERETT W. FRAZAR was married to Miss Maude Wolcott at Grace Church, Waterford, N. Y., on Wednesday, October 7, 1896.

'91.

GEO. C. HOLBERTON has been elected to active membership in the Pacific Coast Gas Association. Mr. Holberton is connected with the Oakland Gas Light and Heat Company.

AT THE ANNUAL DINNER of the Chicago Electrical Association, held May 29, '96, F. A. MUSCHENHEIM responded to the toast "Some Things They Do Better Abroad."

J. T. WALLIS is assistant road foreman of engines of the Philadelphia, Wilmington, and Baltimore R. R. and is located at Wilmington, Del.

'94.

EDWARD P. BUFFETT, JR., is Associate Editor of the *American Machinist*, New York City.

'95.

C. J. PAULDING contributed an article on "The Efficiency of Air Compressors" to the *American Machinist* issued July 9, 1896.

W. H. CORBETT is chief designer in charge of the draughting-room of the Ball & Wood Co., Elizabethport, N. J.

'96.

W. B. OSBORN is in the employ of the Lockport Gas and Electric Light Co., Lockport, N. Y.

ATHLETICS.

FOOTBALL.

After an absence of a year, a 'varsity team will again make its ap pearance on the gridiron to fight for the glory of Stevens.

The inter-class games last fall developed some of the excellent material which is now being made use of; and they were the means of awakening in the individual classes that interest which is such a necessary element in the make up of a representative college team.

The games with Orange and Crescent will be much missed this year, and it is to be regretted that the Middle States League, consisting of Rutgers, Lafayette, and Stevens, has not been re-organized. It was promised last year that arrangements could and would be made to enable Stevens to re-enter the league in 1896, but it has not been done.

Captain Hutchins has been working hard with the team, and the manner in which the men have supported him, gives confidence that a strong aggregation of kickers will represent Stevens on her 'varsity of '96.

The following schedule has been arranged :

Oct. 3.—Elizabeth A. C. at Elizabeth.
" 10.—Y. M. C. A., of the Oranges, at Hoboken.
" 17.—Irving Club at Eastern Park, Brooklyn.
" 21.—Rutgers at New Brunswick.
" 24.—New York University at Ohio Field, N. Y.
" 31.—Elizabeth A. C. at Elizabeth.
Nov. 3.—New Jersey A. C. at Bayonne.
" 7.—Mass. Institute of Technology at Hoboken.
" 11.—Rutgers at Hoboken.

TENNIS.

It is proposed by the tennis club to hold a fall tournament, which is to be conducted on the plan of the spring tournament, in which the class champions were first determined, and the College championship played for by these men. October 5th is the date on which the first round was played.

LACROSSE.

Light practice began October 5th and will continue throughout the winter months. The management is wide awake, and present indications seem to point to a large number of candidates for next year's 'varsity.

By means of this winter's indoor practice, the new men will have an opportunity of becoming perfectly familiar with the ins and outs of the game, while it will benefit the more experienced men by keeping them in constant touch with it.

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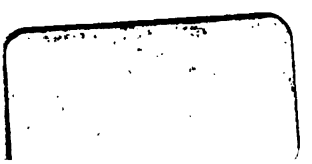
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